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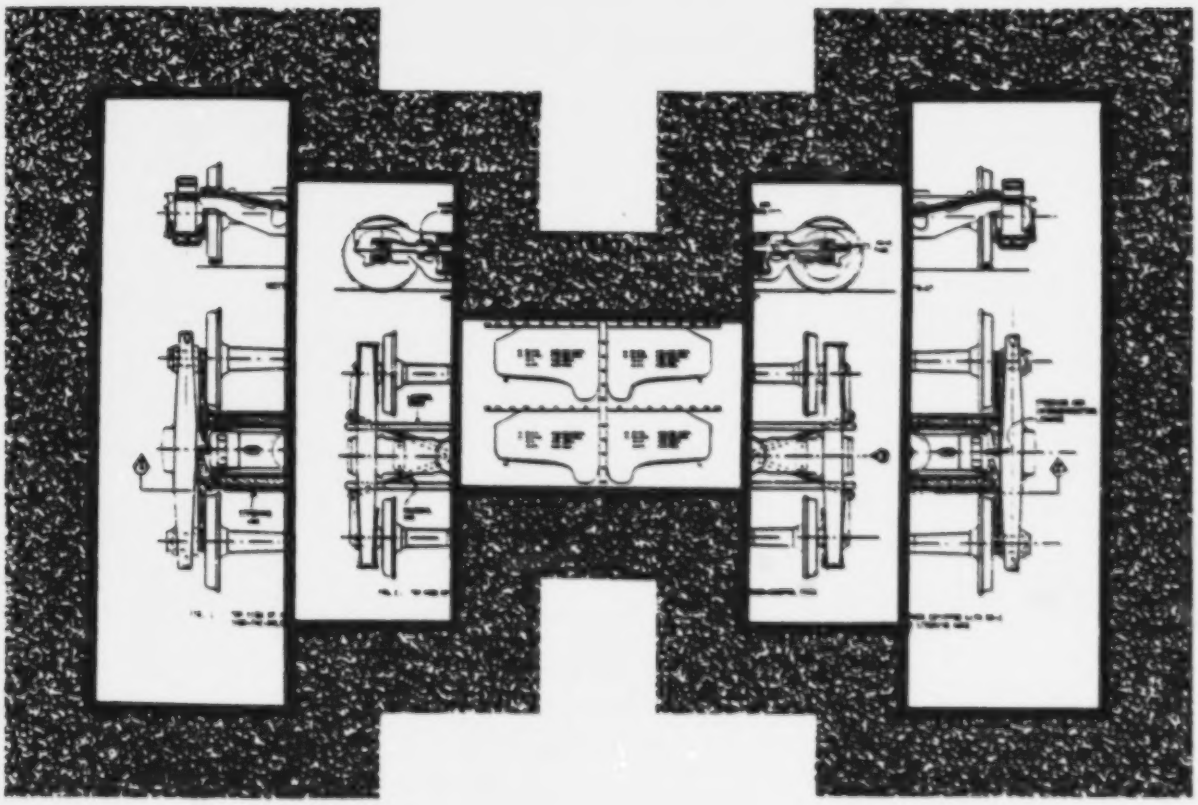
RADIAL AXLE TRUCK TESTS



TECHNICAL AND OPERATIONS RESEARCH

Canadian Pacific

MONTREAL CANADA

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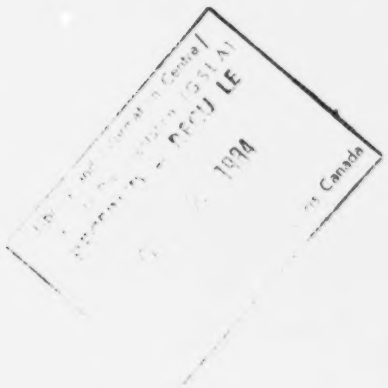
VOLUME 1



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17. Abstract

The Research Department of Canadian Pacific, through a cost sharing agreement with the Transportation Development Centre, initiated a test program to acquire and conduct in-service evaluation tests on Barber-Scheffel and DR-2 self-steering trucks. This report discusses the results of precision wheel wear measurements carried out on wheels of radial and conventional trucks by the use of the wheel profilometer and provides information pertaining to in-service performance of radial trucks.

The results of wheel wear measurements showed that there is a substantial reduction in wheel flange wear on both types of radial trucks compared to conventional Barber S2-C truck wheels. Tread wear on wheels of both types of radial trucks was also reduced. It is expected that similar benefits would occur in terms of reduction in rail head adhesive wear and rail gauge face wear due to the lower lateral creep forces and lower wheelset angle-of-attack experienced by the Barber-Scheffel and the DR-2 trucks.

As part of the radial axle truck test program, a series of hunting and curving performance tests was carried out on elasto-cushion trucks rigidized by means of insertion of a rigid member between the truck side frames. The data from these tests are presently being analyzed. A progress report is provided on the status of this program.

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17. Résumé

Aux termes d'un accord de partage des frais conclu avec le Centre de développement des transports, le Service de la recherche de CP Ltée a lancé un programme d'essais prévoyant l'acquisition et l'évaluation en service d'un certain nombre de bogies orientables de types Barber-Scheffel et DR-2. Ce rapport présente les résultats des mesures faites à l'aide d'un profilomètre de précision pour quantifier l'usure des roues des bogies orientables comparativement à celle des roues de bogies classiques, en plus de renseigner sur le comportement en service des bogies du premier type.

La mesure précise de l'usure des roues a montré une réduction notable de l'usure du boudin sur les roues des deux types de bogies orientables comparativement à celle d'un bogie classique Barber S2-C. Les roues des bogies orientables ont également affiché une usure réduite sur le cercle de roulement. On s'attend aussi que l'utilisation de bogies orientables aura des effets positifs au niveau de l'usure adhésive du sommet du champignon et sur la face intérieure du rail, étant donné les forces transversales et l'angle d'attaque plus faibles autorisés par ces bogies.

Dans le cadre du programme d'essais dont il est question ici, des bogies de type "elasto-cushion" raidis au moyen d'un élément rigide monté entre les longerons ont été soumis à une série d'essais visant à en déterminer le comportement en alignement (phénomène de lacet) et en courbe. En dernier lieu, ce rapport fait le point sur l'état d'avancement du programme d'essais complet.

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essais de bogies orientables, usure roue/rail, roues à profil d'usure, mesure des angles d'inscription	Exemplaires disponible du Centre de développement des transports

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PREFACE

This report presents the results and current status of a series of investigations conducted by the Research Department of Canadian Pacific Limited related to self-steering truck testing.

These research activities are an extension of work initiated to gain a fundamental understanding of the dynamic behaviour of a number of 'new generation' premium trucks.

The following sections summarize the results of earlier truck tests and present in detailed form the results obtained from in-service evaluation testing of the Barber-Scheffel and the DR-2 self-steering trucks. A progress report is also provided to present the current status of curving and hunting performance tests carried out with the rigidized elasto-cushion retrofit truck.

An ambitious research program such as this cannot proceed successfully without the active participation and support of others. We would like to acknowledge such support provided by staff of the Mechanical Department of CP Rail, the Railway Laboratory of the National Research Council of Canada and railway industry colleagues.

Cost-shared financial support provided by the Transportation Development Centre (Transport Canada) permitted our activities to be more vigorous than would have otherwise been possible.

EXECUTIVE SUMMARY

The Research Department of Canadian Pacific, through a cost shared program with the Transportation Development Centre of Transport Canada, initiated a program to acquire and conduct in-service evaluation tests on Barber-Scheffel and DR-2 self-steering trucks. The objective was to determine the extent of wheel life improvement achieved by radial axle truck wheels, compared to the conventional Barber S2-C truck wheels, due to the self-steering characteristics of radial trucks. Precision wheel wear measurements were carried out periodically on the radial and conventional test trucks utilizing a wheel profilometer.

In December 1981, five carsets of Barber-Scheffel trucks were assembled and installed on five 100-ton bathtub coal cars in series CP 352439 to CP 352443, at CP Rail's Ogden Shops in Calgary. Another three bathtub coal cars, namely CP 351530, CP 351581 and CP 351728 were equipped with conventional Barber S2-C trucks for baseline comparison. These cars were placed in unit coal train revenue service operation on January 1, 1982.

The second truck selected for revenue service evaluation was the DR-2 truck, which is a 3-piece conventional truck retrofitted with over-the-bolster steering arms (as opposed to the DR-1 which are retrofitted with through-the-bolster steering arm connections). In May, 1982, five carsets of bathtub coal cars in series CP 352849 to 352853 were equipped with the DR-2 trucks at National Steel Car in Hamilton. They were introduced to revenue service operation on the Pacific Region of CP Rail in June, 1982 and were placed together with the special radial truck test consist of Barber-Scheffel and Barber S2-C trucks. Test cars equipped with DR-2 trucks accumulated approximately 130,000 miles of revenue service operation by mid-October 1983 when they were taken out of revenue service testing because of problems experienced with the steering arm interconnecting linkages. These cars were later re-introduced to revenue service after removal of the DR-2 steering arms.

This report discusses the results of wheel wear measurements carried out on wheels of radial and conventional trucks using two methods, namely, a precision wheel profilometer and a calibrated AAR finger gauge. By automatic matching of new and worn wheel profiles it was possible to obtain loss in wheel flange and tread cross-sectional areas. A calibrated AAR finger gauge was used to measure loss in wheel flange thickness and increase in flange height. Wheel wear data are presented to show wheel wear reduction achieved due to the self-steering characteristics of these trucks. Observations made during field trip inspections are also included.

The results obtained from the finger gauge measurements show that wheel flange wear of both types of radial trucks is approximately 1/4 that of the control cars equipped with conventional trucks. This means that a substantial improvement in wheel life is achieved with the radial axle trucks. From the flange wear vs service mileage trend lines it is evident that wheels on radial trucks will not be condemned for thin flange. Tread wear of wheels on the Barber-Scheffel and the DR-2 trucks was also found to be reduced compared to that experienced by the control cars. The average tread wear of both types of radial trucks obtained from finger gauge measurements was found to be about 78% that of the Barber S2-C trucks after approximately 130,000 miles of revenue service operation.

The flange cross-sectional area loss of the Barber-Scheffel truck wheels was found to be approximately 22% of that developed on wheels of the control cars. Comparable results were obtained from flange cross-sectional area loss computations for the DR-2 truck wheels. The tread cross-sectional area loss on wheels of the DR-2 trucks was higher than the Barber-Scheffel truck wheels at lower mileages. By higher mileages, however, both types of radial trucks had experienced comparable amount of tread cross-sectional area loss, with the Barber-Scheffel truck wheel exhibiting slightly more tread metal removal. On the average the tread cross-sectional area loss of wheels of both radial trucks (which is an indication of the amount of tread metal removal) was found to be approximately 65% that developed on the wheels of the control cars.

From the trend lines of the parametric plot of the average values of flange wear versus tread wear, it was estimated that the self-steering radial truck wheels will likely reach high flange condemning limit, if not removed for any other reason other than normal wear. Based on the tread wear rate of radial truck wheels established at 130,000 miles of revenue service operation, it is expected that first cycle life of a radial truck wheel will exceed 500,000 miles before reaching the high flange condemning limit. This will result in considerable improvement in wheel life of radial trucks as compared to conventional Barber S2-C trucks. Furthermore, as radial truck wheels will have a much larger amount of flange metal (compared to Barber S2-C truck wheels) at the time of wheel profile restoration, it will be possible to restore the original wide flange profile, thus maintaining a good proportion of wheel rim metal, and providing increased second wheel life as compared to conventional truck wheels.

As part of our radial axle truck test program, another candidate retro-fit radial truck - the elasto-cushion truck - was tested. The addition of a rigid member between the truck side frames was designed in order to keep the truck 'square' at all times to avoid truck parallelograming during curve negotiation. Earlier tests carried out on elasto-cushion trucks showed improved curving performance compared to the conventional 3-piece trucks.

A series of curving performance and high speed stability tests was conducted on two 100-ton bathtub coal cars equipped with modified elasto-cushion trucks. Curving tests were carried out on a 5° curve with new Heumann profile wheels while hunting tests were performed with service worn wheels. A progress report is provided which summarizes the current status of this test.

SOMMAIRE EXECUTIF

Aux termes d'un accord de partage des frais conclu avec le Centre de développement des transports, Transports Canada, le Service de la recherche du Canadien Pacifique a lancé un programme d'essais prévoyant l'acquisition et l'évaluation en service de bogies orientables Barber-Scheffel et DR-2. L'objectif était de déterminer le gain réalisable sur la durée de vie utile des roues par l'utilisation de bogies à essieux orientables comparativement aux roues équipant des bogies classiques Barber S2-C. Pour cela, les chercheurs ont mesuré à intervalles réguliers le degré d'usure des roues équipant respectivement des bogies orientables et classiques, utilisant à cette fin un profilomètre de haute précision.

En décembre 1981, cinq wagons-trémies charbonniers de 100 tonnes - CP 352439 à 352443 - ont été équipés de bogies Barber-Scheffel aux ateliers Ogden de CP Rail à Calgary. Trois autres wagons-trémies, nommément les wagons CP 351530, CP 351581 et CP 351728, ont reçu à la même occasion des bogies classiques Barber S2-C pour servir de groupe témoin. Tous ces wagons ont été intégrés à un train-bloc charbonnier exploité en service payant à compter du 1er janvier 1982.

Le deuxième type de bogie orientable soumis à l'évaluation en service payant a été le DR-2, un bogie classique à 3 éléments rééquipé de bras de direction interconnectés au-dessus de la traverse danseuse (contrairement au DR-1 dont les bras de direction sont interconnectés par une biellette traversant cette dernière). Cinq wagons-trémies charbonniers (nº CP 352849 à CP 352853) ont été rééquipés de bogies DR-2 en mai 1982 aux ateliers National Steel Car à Hamilton. Ils ont été mis en service sur le réseau de la région du Pacifique de CP Rail au mois de juin de la même année alors qu'ils ont été intégrés au train-bloc constitué spécialement pour l'évaluation comparative des bogies Barber-Scheffel et Barber S2-C. Les wagons-trémies à bogies DR-2 ont parcouru environ 130 000 miles en service payant avant d'être retirés du service mi-octobre 1983, à cause des problèmes que posaient l'interconnexion des bras de direction. Ces wagons ont été remis en service un peu plus tard après que leurs bogies eurent été dépouillés des bras de direction de type DR-2. Ce rapport présente les résultats des contrôles d'usure auxquels ont été soumises les roues des bogies orientables et classiques à l'essai, contrôles qui ont été réalisés selon deux méthodes distinctes: la profilomètrie de précision et le contrôle par calibre des roue AAR étalonné. La détermination quantitative de la perte de matière sur le boudin et la surface de roulement des roues a été réalisée automatiquement par comparaison des profils d'usure aux profils d'origine. Quant au calibre de roue AAR, il a servi à mesurer l'amincissement du boudin et aussi son gain en hauteur. Les données recuillies sur l'usure des roues sont présentées de manière à mettre en évidence l'usure moindre des roues équipant les bogies orientables. Cette présentation est complétée par des observations pertinentes faites in situ.

Les contrôles par calibre de roue AAR ont montré que l'usure du boudin sur les roues équipant les deux types de bogies orientables testés n'atteignait qu'environ le quart de l'usure constatée sur les bogies classiques. On peut donc s'attendre que les premiers autoriseront un allongement appéciable de la durée de vie des roues. D'ailleurs, à la lecture des graphiques établissant le rapport entre l'usure du boudin et la distance parcourue, il ne fait aucun doute que le retrait des roues orientables ne sera jamais motivé par un amincissement excessif de leur boudin. Pour ce qui concerne l'usure de la surface de roulement, les bogies Barber-Scheffel et DR-2 ont également affiché de meilleurs résultats que les bogies témoins. En effet, les contrôles d'usure par calibre étalonné AAR ont montré après environ 130 000 milles en service payant, une usure moyenne qui atteignait dans le cas des roues orientables quelque 78% seulement de l'usure constatée sur les roues des bogies Barber S2-C.

La réduction de section constatée sur le boudin des roues équipant les bogies Barber-Scheffel était aussi d'environ 78% inférieure à celle des roues témoins. Et les roues des bogies DR-2 ont obtenu des résultats comparables à ce chapitre. Côté surface de roulement, les roues ont accusé une réduction de section plus forte sur les bogies DR-2 que sur les bogies Barber-Scheffel vers le début de la période de contrôle. Mais à mesure que la distance parcourue augmentait, la tendance se renversait, les roues des Barber-Scheffel finissant par accuser une perte de matière légèrement supérieure, même si la réduction de section révélée par le profilomètre était alors comparable. Comparativement aux roues témoins, celles équipant les deux bogies orientables ont autorisé en moyenne une réduction de section sur la surface de roulement (paramètre qui renseigne sur la quantité de métal perdu) d'environ 35% inférieur.

La lecture des graphiques d'usure moyenne des boudins par rapport à l'usure moyenne des surfaces de roulement laisse penser que les roues orientables atteindront la hauteur de boudin limite justifiant leur retrait à moins qu'elles ne soient retirées du service plus tôt pour toute autre raison que l'usure normale. Si l'on se fie à la vitesse d'usure des surfaces de roulement, calculée après 130 000 milles, le premier cycle de vie des roues orientables devrait durer plus de 500 000 milles, la hauteur limite de boudin justifiant le retrait pour reprofilage ne devant être atteint que plus tard. On peut en conclure que la durée de vie des roues orientables sera grandement améliorée comparativement à celle des roues équipant les bogies Barber S2-C. En outre, comme les premières arriveront à l'atelier de reprofilage avec un boudin beaucoup moins aminci que les deuxièmes, il sera possible de leur redonner leur profil épais d'origine sans avoir à sacrifier une épaisseur excessive de leur bande de roulement, leur assurant de la sorte un deuxième cycle de vie allongé par rapport à celui des roues équipant des bogies classiques.

Dans le cadre de notre programme d'essai des bogies orientables, un autre bogie de ce type a été évalué. Il s'agit d'un bogie classique rééquipé de tampons en caoutchouc synthétique pour lui donner une certaine flexibilité radiale et modifié depuis par l'adjonction d'un raidisseurs entre les deux longerons afin d'éviter la déformation du châssis lui-même dans les courbes. Des essais antérieurs avaient déjà montré que les tampons en caoutchouc amélioraient la tenue en courbe par rapport au bogie classique à 3 éléments.

Les essais actuels de tenue en courbe et de stabilité de marche à haute vitesse ont été menés sur deux wagons-trémies charbonniers de 100 tonnes, équipés de bogies de type "elasto-cushion" décrits ci-dessus. Leur tenue en courbe a été vérifiée dans une courbe à 5^{o} alors qu'ils étaient équipés de roues neuves à profil Heumann, tandis que les essais de stabilité de marche (lacet) ont été réalisés sur roues à profil d'usure obtenu en service. Ce rapport fait le point sur l'état d'avancement de ces essais.

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1.0 INTRODUCTION

The need for improved truck curving performance to reduce wheel and rail wear in curved track territories on the Pacific Region of CP Rail, where 100-ton unit coal trains operate, prompted the Canadian Pacific Railway to conduct a series of freight car evaluation tests in 1978 to determine the curving performance and high speed truck stability performance of a number of "new generation" trucks.

During the first phase of this test program the performance of five types of "new generation" trucks was examined. The program consisted of field tests to obtain quantitative data on the performance of various types of improved truck designs. The performance of the Barber S2-C truck was used as a reference for evaluation of the performance of self-steering radial, forced steering and other premium trucks.

The results of Phase I testing indicated that a number of "new generation" truck designs improve both curving and hunting performance compared to existing conventional 3-piece trucks.

As a result of the Phase I findings, the two "most promising" self-steering radial trucks, namely the Barber-Scheffel and the DR-2 trucks were chosen for in-service evaluation in unit coal train operation. The Research Department, through a cost sharing agreement with the Transportation Development Centre, initiated a test program to acquire equipment and conduct in-service evaluation of these trucks. The objective was to evaluate the performance of radial and conventional trucks by monitoring wheel wear.

In December 1981, five carsets of Barber-Scheffel trucks were assembled and installed on five 100-ton bathtub coal cars in series CP 352439 to CP 352443, at CP Rail's Ogden Shops in Calgary. Another three bathtub coal cars namely CP 351530, CP 351581 and CP 351728 were fitted with

conventional Barber S2-C trucks for baseline comparison. These cars were placed in unit coal train revenue service operation in January, 1982. They have since accumulated approximately 190,000 miles of revenue service operation up to the end of December 1983.

The second choice of trucks for revenue service evaluation, the DR-2 truck, is basically a 3-piece conventional truck retrofitted with over-the-bolster steering arms (as opposed to DR-1 trucks which are retrofitted with through the bolster steering arm connections). The DR-2 steering assemblies became available in the latter part of May 1982. Five bathtub coal cars in series CP 352849 to CP 352853 were equipped with the DR-2 trucks at National Steel Car in Hamilton. These cars were introduced to revenue service operation in June, 1982 and were placed together with the Barber-Scheffel truck test consist. They had accumulated approximately 130,000 miles of revenue service up to October 1983 when they were taken out of service because of failure of the spherical bearings imbeded in the steering arm interconnecting links. These cars were re-introduced to revenue service operation without the DR-2 over-the-bolster steering arms.

This report discusses the results of wheel flange and tread wear measurements carried out on the radial axle and the conventional truck wheels. Wheel profiles were measured at approximately 70,000 mile intervals utilizing a wheel profilometer developed by the Research Department of Canadian Pacific. In evaluating radial axle truck wheel wear, comparison is made with wear results from wheels of the three reference bathtub coal cars equipped with the Barber S2-C trucks. Wheel wear data are presented to show the extent of wheel wear reduction achieved due to the self-steering characteristics of these trucks.

2.0 SUMMARY OF PHASE I CURVING PERFORMANCE TEST RESULTS

Curving performance tests were carried out with laden 100-ton bathtub coal cars on a 5 degree mainline track curve with 78 ft. 132 lb. rail. Vertical and lateral forces were measured by applying strain gauges to

the rail web and base at six locations in the test curve. Wheelset angles-of-attack were also measured. The angle-of-attack measuring equipment shown in Figure 1 consists of three low powered lasers and three photo diode detectors.

The measured lateral force data obtained during the tests together with the angle-of-attack data recorded for each wheelset were analyzed to determine the relative curving performance of the five types of "new generation" trucks.

Self-steering radial trucks exhibited a lower level of lateral force between the leading outer wheel of leading and trailing trucks and the high rail compared to the forced steering and other premium trucks tested. The wheelsets of these types of trucks also attained smaller angles-of-attack than the forced steering and the other premium trucks. A detailed description of the other premium trucks tested can be found in Reference 1.

3.0 SUMMARY OF PHASE I HIGH SPEED STABILITY TEST RESULTS

The results of the high speed stability tests indicated that a wide variation in the tracking performance of the conventional Barber S2-C truck can occur, even though the tests were conducted over the same section of track under similar environmental conditions.

The Barber-Scheffel truck exhibited higher dynamical stability compared to the other radial trucks tested. In fact this truck together with one other premium truck tested was stable to 75 mph and showed no tendency towards hunting.

The DR-1 self-steering truck was tested twice, once with conventional springs and again with the CP standard two-stage suspension system utilized on 100-ton coal cars. A much improved ride was obtained with the truck equipped with the two stage suspension system. The high speed stability performance of the DR-1 truck equipped with the two stage suspension system was superior to that of the conventional Barber S2-C truck.

4.0 PHASE II IN-SERVICE EVALUATION TESTS

4.1 Introduction

As a result of the findings from Phase I testing of "new generation" trucks, and at the request of the Mechanical Department of CP Rail, the Research Department, through a cost sharing agreement with the Transportation Development Centre, initiated a test program to acquire equipment and conduct in-service evaluation tests of the two most promising "new generation" trucks. The objective was to gain in-service operating experience while monitoring wheel wear and wear on certain truck components related to the steering mechanism of these radial trucks.

Field inspection of trucks and wheel profile measurements were carried out at Revelstoke, B.C. Each group of cars being tested was inspected twice, once at 70,000 miles and at approximately 130,000 miles. All observations made during field trip inspections are included in progress reports, copies of which are appended to this report. Due to problems experienced with steering arm interconnecting links of the DR-2 trucks, the DR-2 truck test was abandoned after approximately 130,000 miles of revenue service operation. Failure of the "Torrington" spherical bearings imbeded in the steering links was attributed to inadequate bearing dynamic load rating. This condition was aggravated by the absence of a positive locating means for the bearing within the link. The bearings were subjected to downward (vertical) forces higher than the bearing holding friction force thus allowing it to creep out of the link. A new design of the link connection will be provided by Dofasco after which extensive laboratory tests will be carried out on the steering arms before they are re-introduced into revenue service testing. This work will form part of the continued radial axle truck test program in 1984.

Wheel wear was monitored using two methods, the wheel profilometer and a calibrated AAR finger gauge. The results of finger gauge measurements in the form of increase in flange height (tread wear) and loss in flange

thickness (flange wear) are tabulated in Tables 1 to 6. Wheel profiles were also measured using the wheel profilometer developed by the Department of Research of Canadian Pacific. Worn wheel profiles were obtained and plotted for each test car as shown in Figures 9 to 21. The results of finger gauge measurements and wheel cross-sectional area losses are discussed in sections 6, 7 and 8 of this report.

4.2 Test Trucks

The Barber-Scheffel truck incorporates two diagonal bars which pass through the bolster opening and side frames and connect the diagonally opposite shear pad housings. Inter-axle shear stiffness is provided by means of the lateral struts which run parallel to the bolster as shown in Figure 2. Freedom of axles to yaw is obtained by means of shear pads introduced at the side frame pedestal opening.

Figure 3 shows the DR-2 over-the-bolster self-steering retrofit truck arrangement. The dark shaded area shown represents both steering arms of the DR-2 truck. In this design the bearing adaptors form an integral part of the steering arms. The DR-2 is basically a 3-piece conventional truck retrofitted with over-the-bolster steering arms (as opposed to the DR-1 which has a through-the-bolster steering arm connection).

4.3 Test Route

The special radial axle truck test consist was placed in revenue service operation in unit coal train service on the Pacific Region between the coal mines at Fording, and the unloading point at Roberts Bank, some 700 miles away.

The percentage of curvature on this route is approximately 40% as shown in Table 7. The coal trains are turned around every six months, and therefore during a six month period (60,000 miles) bathtub coal cars in unit coal train travel with either 'A' or 'B' end leading.

5.0 WHEEL PROFILE MEASURING SYSTEM

5.1 Wheel Profilometer

Wheel wear measurements were carried out using two methods, one of which made use of a wheel profilometer developed by the Research Department of Canadian Pacific. The concept of this "floating" profilometer is based on the fact that as wheels wear, some areas remain unaffected. By matching these unworn areas the wear of wheel treads and flanges can be calculated. This profilometer also reproduces wheel profiles from data collected and stored on tape during field measurements.

Figure 4 shows a top view of the wheel profilometer mounted on test car wheelset during data collection in the field. The profilometer has three X-Y slides mounted on the base plate. The base plate is attached to a mounting clamp supporting the whole assembly on the measured wheel.

Samples of wheel profiles produced from measurements taken after approximately 130,000 miles of revenue service are shown in Appendix I.

5.2 Data Processing

The data acquisition and logging system is a micro processor based instrument which monitors and records, in a digital format, the X-Y displacement of probes moving along a wheel profile.

The data acquisition system consists of an S-100 bus Z-80 based single board computer, an analog-to-digital converter, a cassette interface and transport system, and a high resolution video board. The operator has access to the system by means of a hexidecimal keypad and can monitor the process of data acquisition through an eight digit display. After retrieval of data, analysis can be accomplished from computer programs.

6.0 WEAR PARAMETERS

Four wheel wear parameters were monitored by the use of the wheel profilometer and also a calibrated AAR finger gauge. Figure 5 shows the method of application of a calibrated AAR steel wheel gauge for measurement of wheel flange and tread wear. From the wheel profiles measured during the field tests and the finger gauge measurements the following information on wheel wear can be obtained:

1. Reduction in wheel flange cross-sectional area.
2. Reduction in wheel tread cross-sectional area.
3. Reduction in wheel flange thickness.
4. Reduction in wheel flange height.

Wheel wear data presented in this section of the report were computed from the calibrated finger gauge measurements.

Tables 1, 2 and 3 show the results of the first set of finger gauge measurements carried out on the Barber-Scheffel, the DR-2 and Barber S2-C trucks. Tables 4, 5 and 6 show the tread and flange wear results obtained at subsequent measurements at higher mileages up to 138,000 miles. In forming a grouped test car average flange and tread wear, only the wear measurements for the most worn wheel of each wheelset was considered. The reason for doing so is that a wheelset is condemned when either of its wheels reaches the flange or tread condemning limit.

Data for the flange and tread wear of three trucks, shown in Tables 1 to 6 (Barber-Scheffel, DR-2 and Barber S-2), were plotted with reference to mileage. In order to fit a line representative of these indices' changes, polynomial regression lines were calculated for each truck's data. The McGill, Music A, Statpak, polynomial regression procedure was used*. Zero points were included in the data matrix, so as to bring the regression line through the origin. Wear was used as the dependant variable and mileage as the independant variable. Having obtained the coefficients for the regression lines of various degrees, these lines were then

*Solving for the equation $Y = B_o + B_1 X_i^1 + B_2 X_i^2 + \ldots + B_n X_i^n$

plotted. The choice of which degree of regression line to be used in each case was based on results of statistical tests carried out to determine best curve fit through the data.

6.1 Flange Wear Data (finger gauge measurements)

Figure 6 shows a plot of the loss in flange thickness as a function of car mileage for the two self-steering trucks and the reference Barber S2-C truck. As mentioned before, data points for flange thickness loss represent the average of four worst wheels of each test car.

It can be easily seen that the trend line for flange wear of the Barber-Scheffel truck wheels is considerably lower compared to that of the standard Barber S2-C wheels. At 130,000 miles, the loss in wheelset flange thickness on the Barber-Scheffel cars is approximately 1/4 that of the control cars equipped with Barber S2-C trucks.

The results of flange wear on cars equipped with DR-2 trucks showed that the DR-2 truck wheels exhibited wear comparable to that of the Barber-Scheffel truck wheels even though the DR-2 trucks had experienced failures of the steering links somewhere between 70,000 and 130,000 miles of service (particulars relating to steering arm interconnecting link failures of DR-2 trucks are discussed in section 9 of this report).

6.2 Tread Wear Data (finger gauge measurements)

Figure 7 shows the plot of the increase in flange height versus service mileage accumulated for each of the cars tested. As can be seen the tread wear on wheels of the Barber-Scheffel trucks is lower than that experienced by the control cars. The average tread wear on the Barber-Scheffel truck cars was found to be 78% of that developed on wheels of the control cars. The DR-2 trucks exhibited higher tread wear at lower mileages as compared to the Barber-Scheffel trucks. However, subsequent measurements of wear at higher mileages indicated that both types of radial trucks exhibited comparable amount of tread wear as can be seen

from the trend lines established in Figure 7. The DR-2 truck exhibited performance comparable to the Barber-Scheffel truck, in terms of tread wear, even though problems with the steering arm interconnecting links existed. There is a possibility that failure of the spherical bearings in the links may have affected truck performance. From the worn wheel profiles plotted, however, it was not possible to establish any unusual pattern that can be related to excessive truck hunting or deteriorated curving performance.

One can also observe that the data for the reference cars are more spread apart indicating a larger spread in average wheel wear between the control cars as compared to the radial axle truck cars. The wear data for both types of steerable-axle trucks are less scattered at lower mileages but the Barber-Scheffel truck data tends to spread apart after approximately 130,000 miles of service.

6.3 Combined Tread and Flange Wear Data (finger gauge measurements)

Computed average values for flange wear and tread wear were used to establish the parametric plot shown in Figure 8.

It can be seen that the trend line for the reference car is directed towards the thin flange condemning limit established by the AAR to be .58" for a wide flange Heumann contour wheel. On the other hand the Barber-Scheffel and the DR-2 car trend lines indicates that those wheels are bound to reach the high flange condemning limit which is 0.45 inches.

When wheels are condemned for thin flange, a considerable amount of metal from the flange tip and wheel tread is removed in order to restore a new wheel profile. This condition is definitely not desirable and it is evident that the wheels of Barber-Scheffel cars and cars equipped with the DR-2 trucks are more prone to be condemned for high flange and therefore will have more rim metal left after reprofiling of their wheels. In fact, it will be possible to reprofile the radial truck wheels to a wide flange profile, thus increasing its life considerably.

Therefore it is evident that the performance of the Barber-Scheffel and the DR-2 trucks is superior to the reference Barber S2-C trucks as wheels, if not removed for any other reason other than normal wear, will be condemned for high flange and therefore when reprofiling only a small proportion of the rim metal will be lost. Furthermore, the radial axle truck wheel life (first life, before reprofiling) is expected to be much higher as compared to the conventional truck wheel.

7.0 DISCUSSION OF WHEEL WEAR PATTERN

Worn wheel profiles collected after approximately 125,000 to 135,000 miles of revenue service operation were processed and plotted against initial wheel profiles by means of a computer program developed for matching wheel profiles and calculating flange and tread cross-sectional area losses. These profiles were obtained for each wheel of the radial axle and conventional trucks and plotted for each car indicating position of wheelset as shown in Figures 9 to 21. Results of tread and flange cross-sectional area losses for each of the wheels are also provided. Tread and flange wear results shown have been also calculated by means of a computer for comparison with results obtained with the finger gauge measurements.

7.1 Wheel Profiles of the Barber-Scheffel Trucks

Matched new and worn wheel profiles shown in Figures 9 to 13 inclusive are for the five carsets of bathtub coal cars equipped with the Barber-Scheffel trucks. With the exception of wheelset #1 on car CP 352441 and wheelset #2 on car CP 352442, the very little amount of flange wear experienced by the wheels of these trucks is evenly distributed between both wheels of an axle. The wear on the R1 wheel of car CP 352441 was considerably higher than the L1 wheel and similarly the L2 wheel exhibited more wear as compared to the R2 on car CP 352442. The reason for this difference in flange wear between wheels of the same axle may be due to an initial slight mismatch of wheels. It appears that the profile of the tread portion of the wheels attain a common worn wheel profile, as has been demonstrated in earlier tests carried out with 'A' and 'AAR' profile wheels.

7.2 Wheel Profiles of the DR-2 Trucks

Worn wheel profiles of the DR-2 trucks are shown in Figures 14 to 18. Wheel wear as seen from the plotted wheel profiles is very similar to the wear pattern experienced on the Barber-Scheffel truck wheels. With the exception of few wheelsets, the small amount of flange wear experienced by the wheels of the DR-2 trucks is evenly distributed among both wheels of an axle. Problems developed in the steering arm interconnecting linkages may have caused wheelset lateral tracking to one side, thus causing this difference in flange wear between wheels of these few wheelsets. Of particular interest, is the fact that diagonally opposite wheels of a truck experienced more flange wear as can be seen from wheel profiles of car CP 352849 shown in Figure 14. The tread wear pattern of the DR-2 truck wheels was found to be similar to the Barber-Scheffel truck wheels.

7.3 Wheel Profiles of the Barber S2-C Trucks

New and worn wheel profiles of the Barber S2-C trucks shown in Figure 19 to 21 clearly indicate that these trucks are inferior to the radial axle trucks as far as wheel flange and tread wear is concerned. Flange wear was found to be considerably higher for this type of truck as can be seen from the plotted wheel profiles. Wheels on car CP 351530 exhibited more flange wear of the right hand wheels of the 'B' end truck and left hand wheels on the 'A' end. The same wear pattern was observed on wheel profiles of car CP 351581 shown in Figure 20. This wear pattern may have arisen from a small initial diameter mismatch that may have caused lateral tracking of these axles to one side. This condition can be aggravated if wheelsets on the same truck are slightly misaligned, i.e. are not kept parallel to each other. One can also notice that wheelsets #3 on car CP 351530 and CP 351728 were changed out at 95,000 and 111,000 miles.

8.0 CROSS-SECTIONAL AREA LOSSES

Wheel tread and flange cross-sectional area data was extracted automatically through the use of wheel profilometer software by matching new

and worn wheel profiles. New and worn wheel profiles together with the amount of flange and tread cross-sectional area losses can be found in Figures 9 to 21 of this report. To compute the flange and tread cross-sectional area losses, a point of separation between the two regions had to be defined. CN's method of defining the point of separation between the tread portion and the flange portion of the wheel was chosen in order to be able to compare results of wheel wear of both railways. This point is taken as the 45° tangent point in the wheel throat fillet radius on a new wide flange Heumann profile wheel and was found to be 1.53" from the wheel back face.

8.1 Tread Area Wear

Figure 22 shows the plot of the tread wear area reduction versus service mileage accumulated for the Barber-Scheffel, the DR-2 and Barber S2-C truck wheels. From regression analyses performed the linear regression presented the best fit to the wear data collected for both types of trucks as shown in Figure 22. Wear area shown is averaged for all wheels of each test car.

As can be observed, there is a clear reduction in tread wear for both self-steering radial compared to the conventional trucks. The average tread wear on wheels of the DR-2 trucks is higher than the Barber-Scheffel truck wheels up to about 90,000 miles after which the two trend lines cross each other resulting in slightly lower tread area wear for the DR-2 truck wheels at higher mileages.

The tread cross-sectional area loss for the Barber-Scheffel trucks was found to be approximately 65% that developed on wheels of the control cars after 130,000 miles of revenue service operation. This indicates that the self-steering capability of radial trucks has been exploited as lower lateral creep forces developed during curve negotiation have resulted in less tread wear occurrence on wheels of the radial trucks as compared to the conventional ones. It should be noted, however, that there is an unknown amount of tread wear caused by the brake shoes. This should be considered in determining the extent of benefits obtained

from the reduced lateral creep forces. It is also expected that benefits would occur in terms of reduction in rail head adhesive wear, due to lower lateral creep experienced by the Barber-Scheffel and DR-2 trucks.

Another interesting observation that can be made from Figure 22 is how closely the points representing average tread wear on wheels of radial trucks measured only within two thousand miles spread, are clustered. This indicates a consistency in performance between trucks of similar kind.

8.2 Flange Area Wear

Figure 23 shows a plot of flange area wear as a function of service mileage accumulated for wheels of the Barber-Scheffel, DR-2 and the Barber S2-C trucks. Each point shown in Figure 23 represents the average flange wear area of all eight wheels of each test car.

From the trend lines shown in Figure 23, it is evident that the flange wear experienced by both the Barber-Scheffel and the DR-2 equipped cars is much lower than the control cars. Here again, trend lines for both radial trucks are close to each other. At 140,000 miles of service the flange cross-sectional area loss for the Barber-Scheffel cars is approximately 22% of that developed on the control cars. The DR-2 truck's performance is slightly poorer, but the difference in wear of both types of radial trucks is so small that it can be considered to be similar for all practical purposes. It is also expected that benefits would occur in terms of reduction in rail gauge face wear, due to lower wheelset angle-of-attack experienced by the Barber-Scheffel and the DR-2 trucks.

9.0 OBSERVATIONS MADE DURING FIELD TRIP INSPECTIONS

Truck inspection and wheel profile measurements of the radial truck test consist were carried out regularly every 65,000 to 70,000 miles. Progress reports appended to this report describe in detail observations made

during the field trips. It is worthwhile mentioning here the circumstances that lead to the abandonment of the DR-2 truck testing as a result of a number of failures associated with the steering mechanism of these trucks.

The first incidence of failure was observed during field trip inspection of the DR-2 trucks on March 9, 1983 at Revelstoke. During inspection of the steering arms of the DR-2 trucks, it was observed that a number of steering arm interconnecting links had damaged spherical bearings which are embeded in the links.

As a result of these findings, an alternate spherical bearing which incorporates a teflon-based self-lubricating liner between the ball and the outer race were applied to a new set of fabricated links. All DR-2 truck steering linkages were replaced with these new linkages. This work was carried out in May, 1983 at Revelstoke. At the time of truck modification these cars had accumulated an average of 70,000 miles of revenue service operation.

The DR-2 radial axle truck test consist continued to operate until September 28, 1983 when it was taken from revenue service at 130,000 miles for inspection and wheel profile measurements. During inspection, it was observed that the steering arm interconnecting linkages had again failed indicating that the design was not adequate to withstand forces developed between the steering arms. It was at this point that the DR-2 truck testing was suspended. It is expected that a new design of the steering arm interconnecting linkage will be available soon for testing. This will form part of our radial axle truck testing to be carried out in 1984.

CONCLUSIONS

1. After approximately 130,000 miles of revenue service operation, the average flange wear on the Barber-Scheffel cars obtained from finger gauge measurements is approximately 1/4 that of the control cars equipped with Barber S2-C trucks. From the Barber-Scheffel truck wheel flange wear rate established at 130,000 miles of service, it is evident that these wheels will not be condemned for thin flange. The Barber-Scheffel truck wheels will be condemned for high flange if not removed for any defects other than normal wear.

2. Even though problems were experienced with the steering links of the DR-2 trucks, the average flange wear on the DR-2 cars obtained from finger gauge measurements is also approximately 1/4 that of the control cars after 130,000 miles of revenue service operation. Failure of the spherical bearings may have affected the DR-2 truck's curving and high speed stability performance.

3. From field measurements carried out utilizing an AAR calibrated finger gauge, the average tread wear of wheels of both radial trucks was found to be about 78% that of the Barber S2-C trucks after approximately 130,000 miles of service. Based on tread wear rates of radial truck wheels established at 130,000 miles of revenue service operation, it is expected that wheel life of Barber-Scheffel truck wheels will exceed 500,000 miles before reaching the high flange condemning limit.

4. From wheel profiles collected utilizing the wheel profilometer, the flange cross-sectional area loss for the Barber-Scheffel trucks was found to be approximately 22% of that developed on wheels of the control cars. The tread cross-sectional area loss on wheels of the Barber-Scheffel trucks was found to be approximately 65% that developed on wheels of the control cars.

5. The flange cross-sectional area loss of wheels of the DR-2 trucks was found to be comparable to that of the Barber-Scheffel trucks. The tread cross-sectional area loss on wheels of the DR-2 trucks was slightly higher than the loss experienced by wheels of the Barber-Scheffel trucks up to about 90,000 miles and slightly lower at higher mileages.

6. The trend lines established from the parametric plot of average values of flange wear versus tread wear indicate that the self-steering radial truck wheels will be condemned for high flange and the Barber S2-C truck wheels for thin flange.

7. As radial axle truck wheels will have a much larger amount of flange metal available (compared to the Barber S2-C truck wheels) at the time of wheel profile restoration, it will be possible to restore the original wide flange profile, always maintaining a good proportion of wheel rim metal, thus providing increased second wheel life compared to the conventional truck wheels.

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Table 1: Bathtub Coal Cars Equipped With Barber-Scheffel Trucks
Wheel Wear Results Obtained by the Use of a Calibrated
AAR Finger Gauge During First Scheduled Truck Inspection
Carried Out at Revelstoke, B.C. on September 30, 1982

Increase in Flange Height (inches)
Wheelset Position

Car No.	Mileage	'B' End				'A' End				Average
		R1	L1	R2	L2	R3	L3	R4	L4	
CP 352439	63,929	4/64	4/64	3/64	2/64	6/64	5/64	4/64	5/64	$\frac{4.5}{64} = .070$
CP 352440	78,380	6/64	5/64	5/64	6/64	4/64	3/64	5/64	5/64	$\frac{5.25}{64} = .082$
CP 352441	72,343	6/64	5/64	8/64	4/64	4/64	4/64	5/64	5/64	$\frac{5.75}{64} = .090$
CP 352442	70,933	2/64	2/64	3/64	2/64	2/64	3/64	5/64	3/64	$\frac{3}{64} = .047$
CP 352443	79,422	5/64	5/64	5/64	5/64	5/64	4/64	5/64	5/64	$\frac{4.75}{64} = .074$

Loss in Flange Thickness (inches)
Wheelset Position

Car No.	Mileage	'B' end				'A' End				Average
		R1	L1	R2	L2	R3	L3	R4	L4	
CP 352439	63,929	.040	.055	.050	.020	.045	.020	.010	.050	.044
CP 352440	78,380	.085	.015	.030	.025	.005	.030	.040	.030	.046
CP 352441	72,343	.150	.005	.020	.045	.035	.040	.035	.020	.067
CP 352442	70,933	.030	.030	.025	.105	.050	.055	.025	.030	.055
CP 352443	79,422	.030	.030	.025	.025	0	0	.025	.045	.025

Note: Average values shown are based on the worst wheel of each wheelset.

Table 2: Bathtub Coal Cars Equipped With DR-2 Trucks Wheel Wear Results Obtained by the Use of a Calibrated AAR Finger Gauge During First Scheduled Truck Inspection Carried Out at Revelstoke, B.C. on March 9, 1983

Increase in Flange Height (inches)
Wheelset Position

Car No.	Mileage	'B' End R1	L1	R2	L2	'A' End R3	L3	R4	L4	Average
CP 352849	70,137	5/64	6/64	5/64	8/64	5/64	2/64	2/64	5/64	$\frac{4.75}{64}$ = .0742
CP 352850	67,137	2/64	5/64	1/64	7/64	4/64	3/64	3/64	5/64	$\frac{3.75}{64}$ = .0586
CP 352851	69,137	10/64	5/64	5/64	4/64	2/64	5/64	1/64	5/64	$\frac{4.625}{64}$ = .0722
CP 352852	69,137	6/64	3/64	2/64	4/64	6/64	2/64	5/64	4/64	$\frac{4}{64}$ = .0625
CP 352853	68,137	3/64	6/64	1/64	7/64	6/64	6/64	3/64	6/64	$\frac{4.75}{64}$ = .0742

Loss in Flange Thickness (inches)
Wheelset Position

Car No.	Mileage	'B' end R1	L1	R2	L2	'A' End R3	L3	R4	L4	Average
CP 352849	70,137	.075	0	.015	.025	.0375	.0125	.0125	.0125	.0375
CP 352850	67,137	.0825	.050	.0125	.0125	.0625	.025	.050	.0375	.0520
CP 352851	69,137	.0125	.0625	0	.015	.045	.050	.0375	0	.0412
CP 352852	69,137	.075	.025	.025	0	.0125	.095	.020	.050	.0612
CP 352853	68,137	.0625	.025	.0125	.0125	0	.125	.0125	.008	.0531

Note: Average values shown are based on the worst wheel of each wheelset.

Table 3: Bathtub Coal Cars Equipped With Barber S2-C Trucks
Wheel Wear Results Obtained by the Use of a Calibrated
AAR Finger Gauge During First Scheduled Truck Inspection
Carried Out at Revelstoke, B.C. on September 30, 1982

Increase in Flange Height (inches)
Wheelset Position

Car No.	Mileage	'B' End				'A' End				Average
		R1	L1	R2	L2	R3	L3	R4	L4	
CP 351530	53,811	6/64	3/64	5/64	4/64	4/64	5/64	5/64	7/64	$\frac{5.75}{64} = .089$
CP 351581	79,151	7/64	6/64	6/64	6/64	5/64	5/64	6/64	7/64	$\frac{6.25}{64} = .097$
CP 351728	76,754	6/64	10/64	7/64	6/64	5/64	5/64	5/64	9/64	$\frac{7.5}{64} = .117$

Loss in Flange Thickness (inches)
Wheelset Position

Car No.	Mileage	'B' end				'A' End				Average
		R1	L1	R2	L2	R3	L3	R4	L4	
CP 351530	53,811	.155	.085	.175	.100	.085	.125	.085	.110	.141
CP 351581	79,151	.300	.100	.145	.045	.150	.200	.100	.075	.186
CP 351728	76,754	.150	.300	.085	.175	.130	.205	.105	.085	.196

Note: 1. Average values shown are based on the worst wheel of each wheelset.

Table 4: Bathtub Coal Cars Equipped With Barber-Scheffel Trucks
Wheel Wear Results Obtained by the Use of a Calibrated
AAR Finger Gauge During Second Scheduled Truck Inspection
Carried Out at Revelstoke, B.C. on May 10, 1983.

Increase in Flange Height (inches)
Wheelset Position

Car No.	Mileage	'B' End				'A' End				Average
		R1	L1	R2	L2	R3	L3	R4	L4	
CP 352439	123,204	7/64	6/64	6/64	6/64	8/64	8/64	5/64	6/64	$\frac{6.75}{64} = .105$
CP 352440	138,360	8/64	7/64	6/64	9/64	7/64	6/64	8/64	8/64	$\frac{1}{8} = .125$
CP 352441	121,114	8/64	9/64	7/64	5/64	7/64	5/64	7/64	7/64	$\frac{7.5}{64} = .117$
CP 352442	130,913	4/64	5/64	4/64	3/64	5/64	5/64	5/64	5/64	$\frac{4.75}{64} = .074$
CP 352443	122,312	7/64	10/64	10/64	6/64	8/64	6/64	6/64	7/64	$\frac{8.75}{64} = .136$

Loss in Flange Thickness (inches)
Wheelset Position

Car No.	Mileage	'B' end				'A' End				Average
		R1	L1	R2	L2	R3	L3	R4	L4	
CP 352439	123,204	0	.025	.050	.025	.025	0	0	.050	.0375
CP 352440	138,360	.050	.025	0	-.025	-.050	0	0	0	.0125
CP 352441	121,114	.175	0	.025	.025	0	0	0	0	.050
CP 352442	130,913	.025	0	0	.150	0	.025	0	0	.050
CP 352443	122,312	.025	.025	.050	-.025	-.050	0	0	.025	.025

Notes:
1. Negative sign denotes increase in flange thickness
2. Average values shown are based on the worst wheel of each wheelset.
3. Negative values were not considered when calculating average values.

Table 5: Bathtub Coal Cars Equipped With DR-2 Trucks Wheel Wear Results Obtained by the Use of a Calibrated AAR Finger Gauge During Second Scheduled Truck Inspection Carried Out at Revelstoke, B.C. on September 29, 1983

Increase in Flange Height (inches)
Wheelset Position

Car No.	Mileage	'B' End R1	L1	R2	L2	'A' End R3	L3	R4	L4	Average
CP 352849	118,542	7/64	8/64	8/64	9/64	5/64	2/64	4/64	8/64	$\frac{7.5}{64} = .117$
CP 352850	124,056	5/64	4/64	5/64	9/64	6/64	4/64	4/64	8/64	$\frac{7}{64} = .109$
CP 352851	124,596	8/64	5/64	8/64	8/64	6/64	7/64	6/64	6/64	$\frac{7.25}{64} = .113$
CP 352852	124,595	6/64	6/64	6/64	6/64	10/64	2/64	5/64	6/64	$\frac{7}{64} = .109$
CP 352853	125,058	7/64	6/64	4/64	9/64	7/64	7/64	2/64	8/64	$\frac{7.5}{64} = .117$

Loss in Flange Thickness (inches)
Wheelset Position

Car No.	Mileage	'B' end R1	L1	R2	L2	'A' End R3	L3	R4	L4	Average
CP 352849	118,542	.050	.037	0	.062	.025	0	0	.025	.040
CP 352850	124,056	.020	.012	.012	.025	.0125	.012	0	.037	.020
CP 352851	124,596	-.0125	.050	0	-.035	.007	-.025	.025	.012	.020
CP 352852	124,595	.050	-.012	.025	-.037	-.012	.070	.020	.037	.045
CP 352853	125,058	.012	0	-.025	0	-.037	.075	-.102	.012	.025

Notes:
1 - Negative sign denotes increase in flange thickness
2 - Average values shown are based on the worst wheel of each wheelset.
3. Negative values were not considered when calculating average values.

Table 6: Bathtub Coal Cars Equipped With Barber S2-C Trucks
Wheel Wear Results Obtained by the Use of a Calibrated
AAR Finger Gauge During Second Scheduled Truck Inspection
Carried Out at Revelstoke, B.C. on May 10, 1983.

Increase in Flange Height (inches)
Wheelset Position

Car No.	Mileage	'B' End				'A' End				Average
		R1	L1	R2	L2	R3	L3	R4	L4	
CP 351530	104,670	8/64	6/64	9/64	7/64	2/64*	5/64*	8/64	18/64	$\frac{11.6}{64}$ = .182
CP 351581	138,878	10/64	11/64	11/64	9/64	9/64	8/64	10/64	10/64	$\frac{10.25}{64}$ = .160
CP 351728	130,666	10/64	9/64	8/64	9/64	2/64	2/64	9/64	10/64	$\frac{7.75}{64}$ = .121

Loss in Flange Thickness (inches)
Wheelset Position

Car No.	Mileage	'B' end				'A' End				Average
		R1	L1	R2	L2	R3	L3	R4	L4	
CP 351530	104,670	.150	.075	.225	.075	.050*	.050*	.075	.250	.208
CP 351581	138,878	.300	050	.200	.050	.125	.150	.075	.075	.181
CP 351728	130,666	.125	.225	.100	.150	.100	.250	.200	.075	.231

Notes: 1 - Data marked with asterisks indicate wheelset changeout had occurred.

2 - Average values shown are based on the worst wheel of each wheelset.

DEGREE OF CURVE	MOUNTAIN 125.71	SHUSWAP SINGLEAST 128.52	SHUSWAP WEST 24.73	WINDERMERE 142.52	CRANBROOK 107.64	CASCADE SINGLEAST 109.58	CASCADE WEST 56.71	THOMPSON SINGLEAST 121.52.	THOMPSON WEST 8.68	Total Route
0° 01' - 0° 59'	0.42	0.83	3.91	0.21	0.19	1.38	1.67	1.58	-	0.75
1° 00' - 1° 59'	2.96	7.87	8.40	3.20	4.24	4.71	4.50	4.12	3.77	4.50
2° 00' - 2° 59'	3.41	4.55	5.75	8.68	8.36	8.89	10.48	7.10	4.12	6.78
3° 00' - 3° 59'	4.50	3.42	2.63	7.06	3.12	7.11	5.14	8.36	6.07	5.63
4° 00' - 4° 59'	5.84	3.54	2.91	6.95	4.66	4.67	3.94	9.79	7.94	5.95
5° 00' - 5° 59'	3.52	2.65	-	4.03	3.55	3.75	0.93	5.56	9.03	3.84
6° 00' - 6° 59'	7.05	3.11	-	3.62	5.11	1.47	0.19	5.94	8.23	4.39
7° 00' - 7° 59'	1.21	1.12	-	1.41	2.57	1.37	-	3.75	-	1.87
8° 00' - 8° 59'	6.67	3.62	-	1.18	0.57	2.32	-	5.68	-	3.36
9° 00' - 9° 59'	0.70	0.17	-	0.30	0.91	0.05	-	1.05	-	0.52
10° 00' - 10°59'	4.58	-	-	0.81	0.90	-	-	1.11	-	1.25
11° 00' - 11°59'	0.39	-	-	-	0.20	-	-	0.40	-	0.16
12° 00' - 12°59'	-	-	-	-	0.67	-	-	0.05	-	0.10
TANGENT	58.75	69.12	76.40	62.55	64.95	64.28	73.15	45.51	60.84	60.90

TABLE 7: PERCENT OF TRACK MILES BY DEGREE OF CURVE
R.M.M.S. DATA BASE

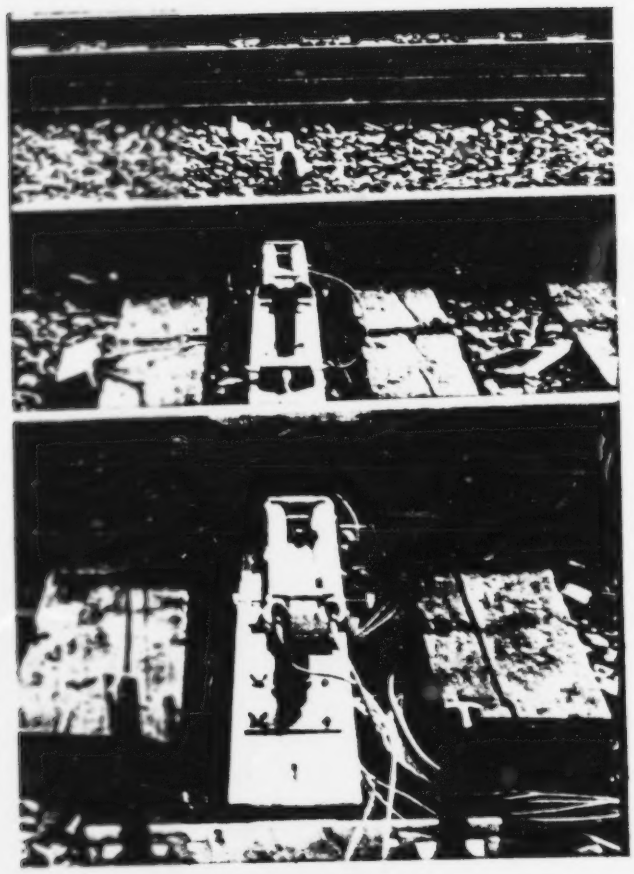
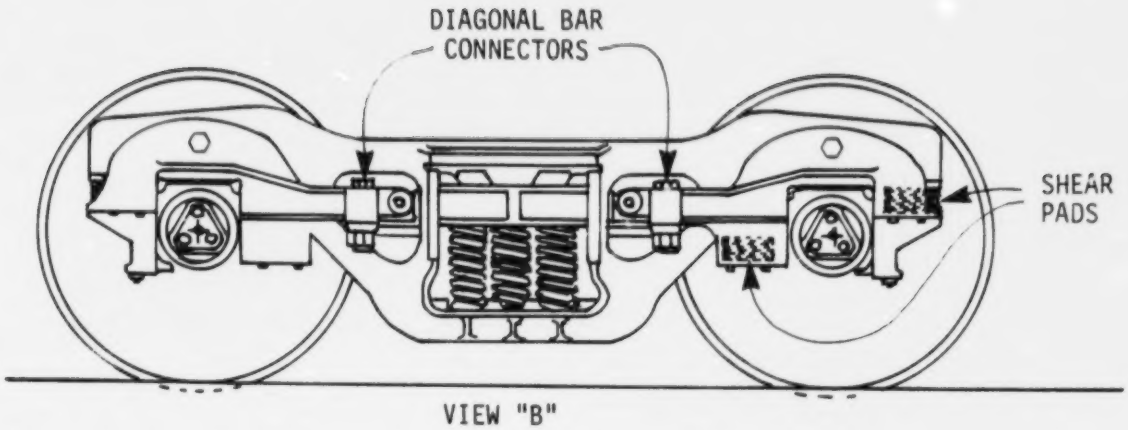


FIG. 1 ANGLE-OF-ATTACK MEASUREMENT SYSTEM



VIEW "B"

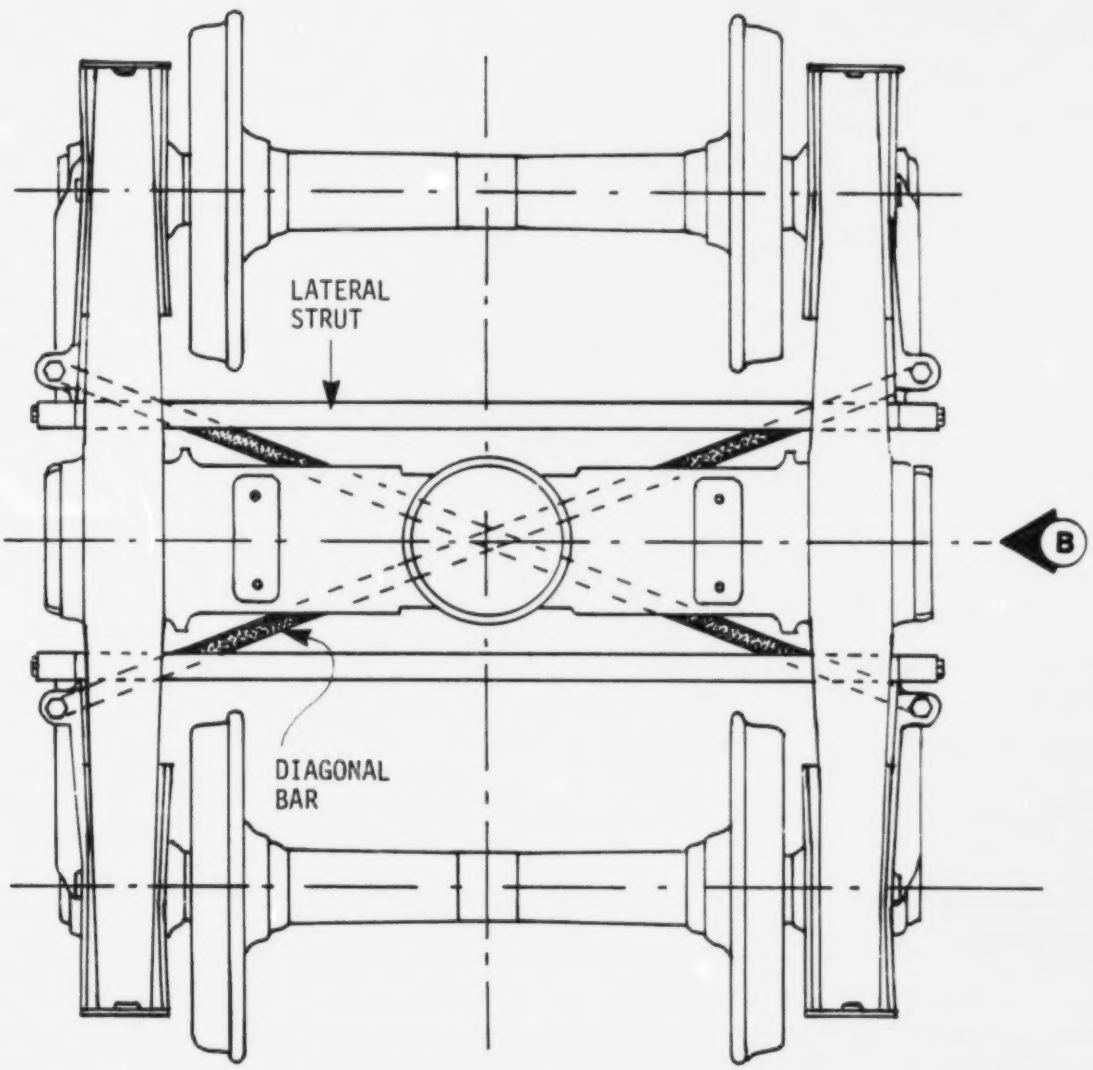
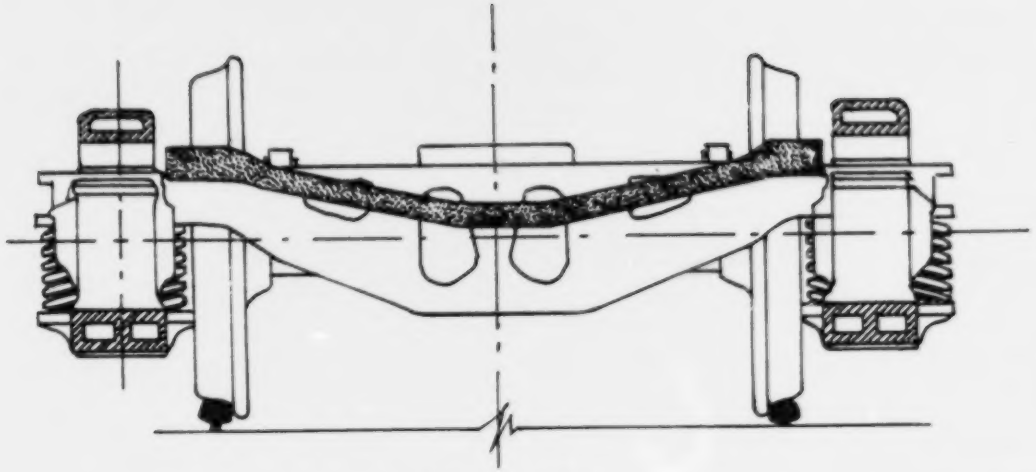


FIG. 2 : TOP VIEW OF BARBER-SCHEFFEL TRUCK



SECTION "A-A"

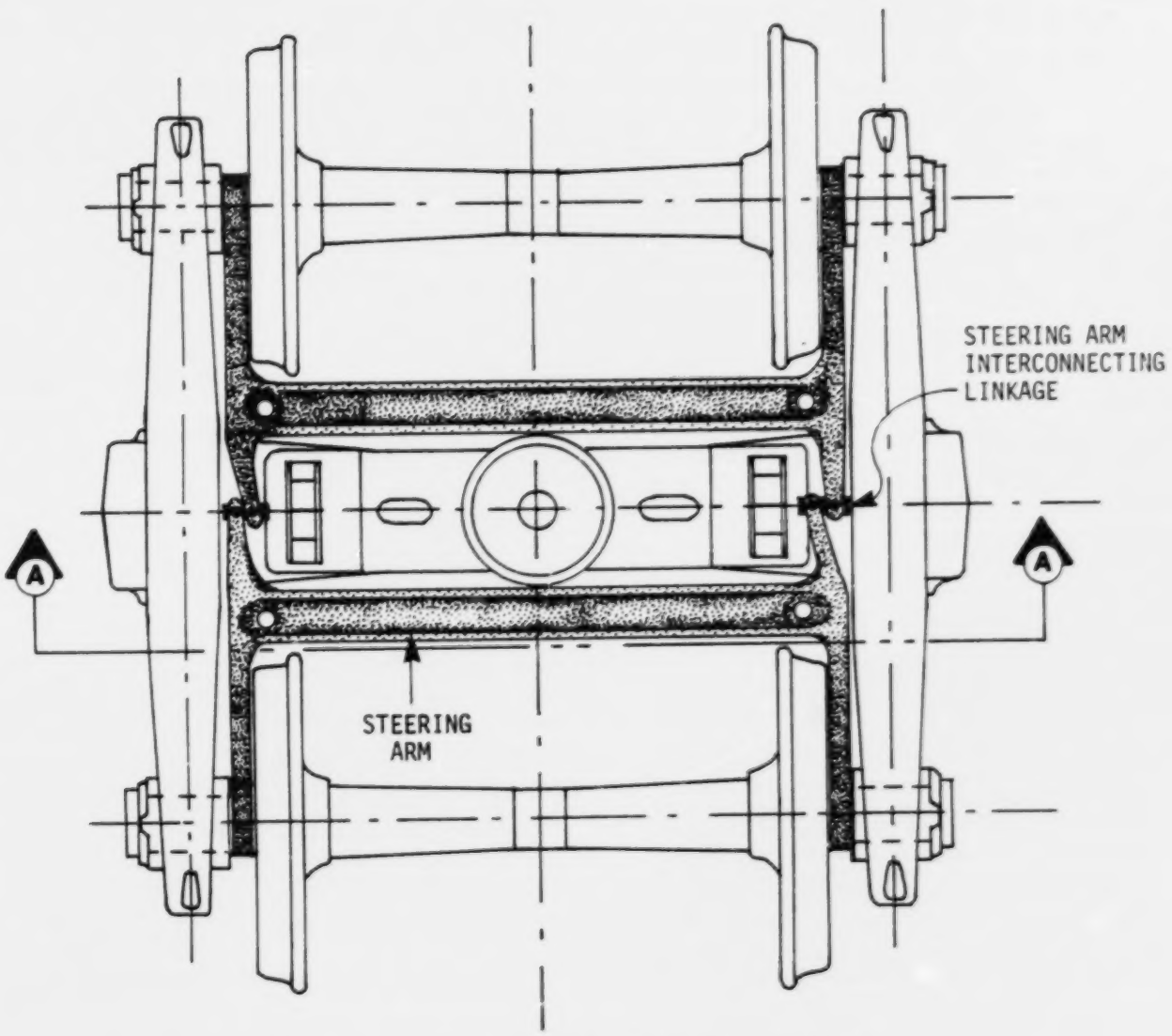


FIG. 3 : TOP VIEW OF A TRUCK EQUIPPED WITH DR-2
OVER-THE-BOLSTER STEERING ARMS

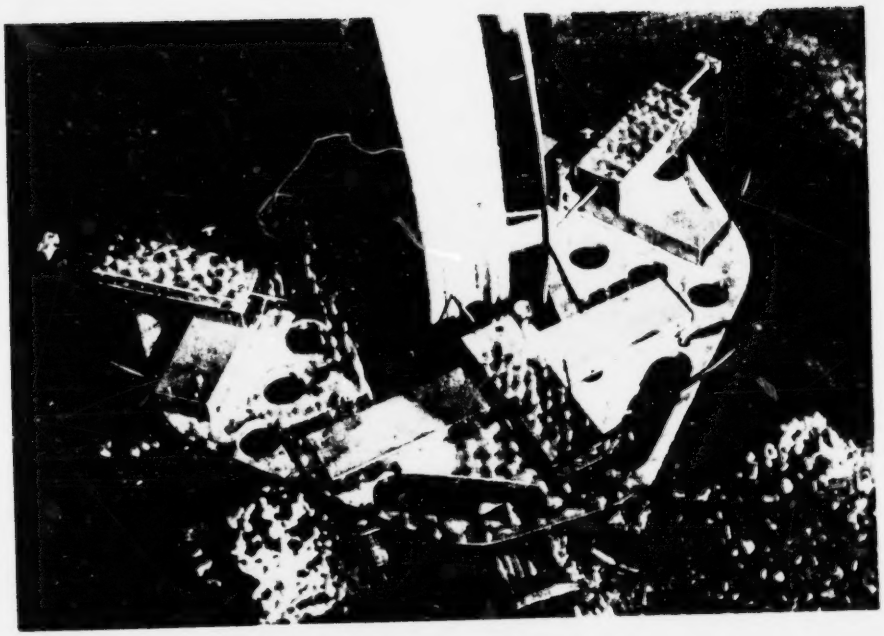


FIG. 4 - TOP VIEW SHOWING NEW WHEEL PROFILOMETER MOUNTED ON TEST TRUCK WHEELSET

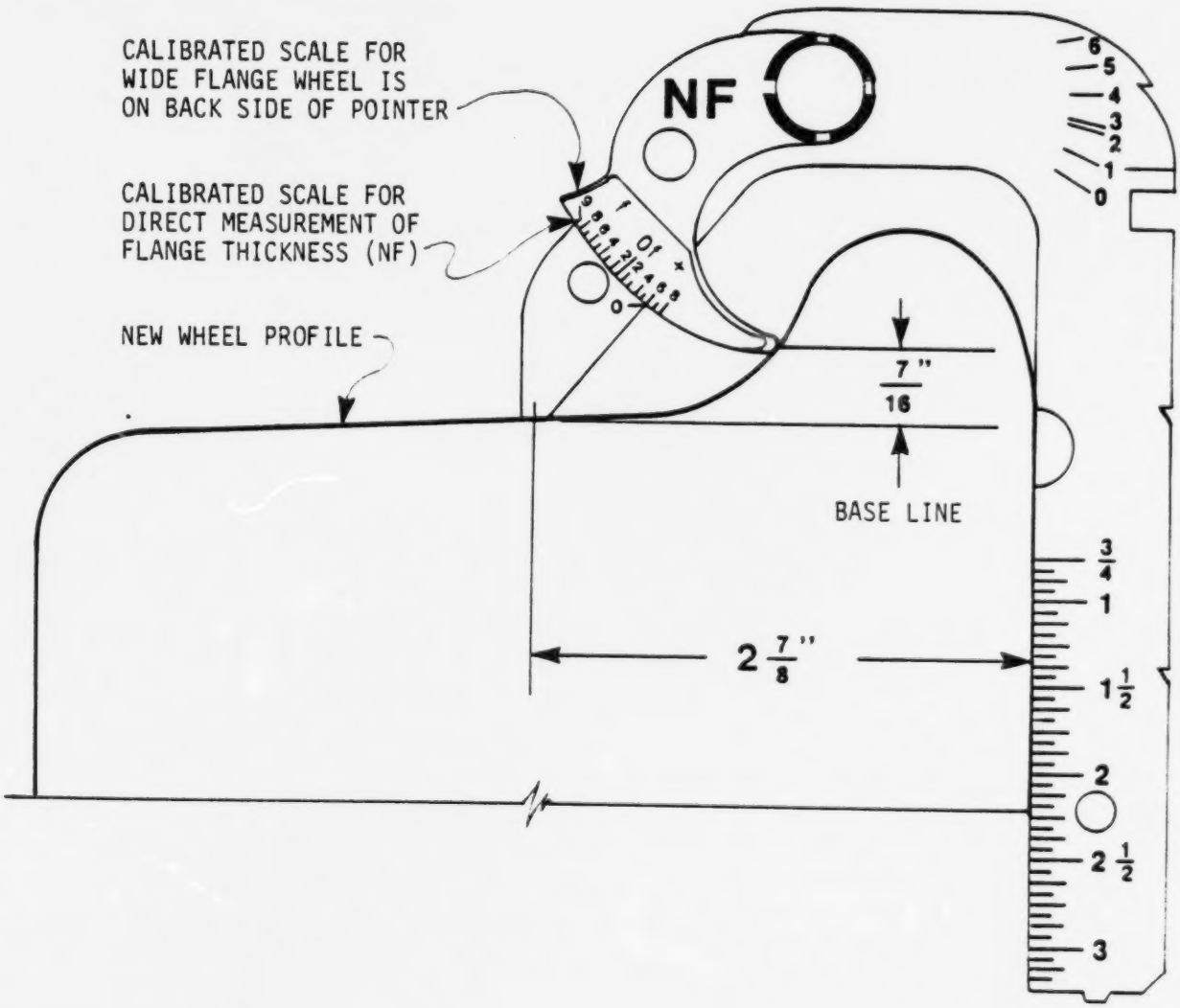


FIG. 5 : A.A.R. CALIBRATED WHEEL GAUGE

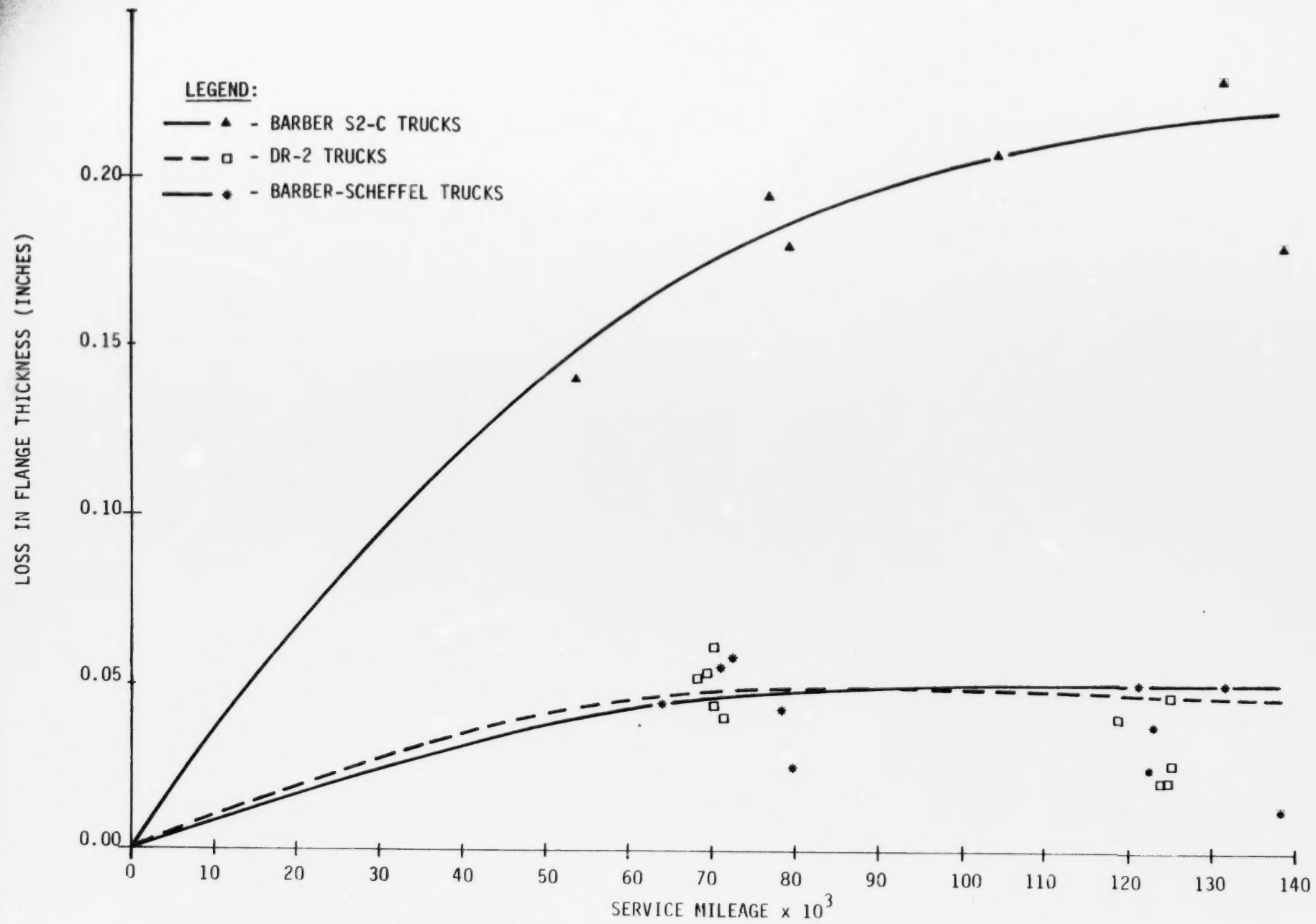


FIG.6 : LOSS OF WHEEL FLANGE THICKNESS VERSUS SERVICE MILEAGE

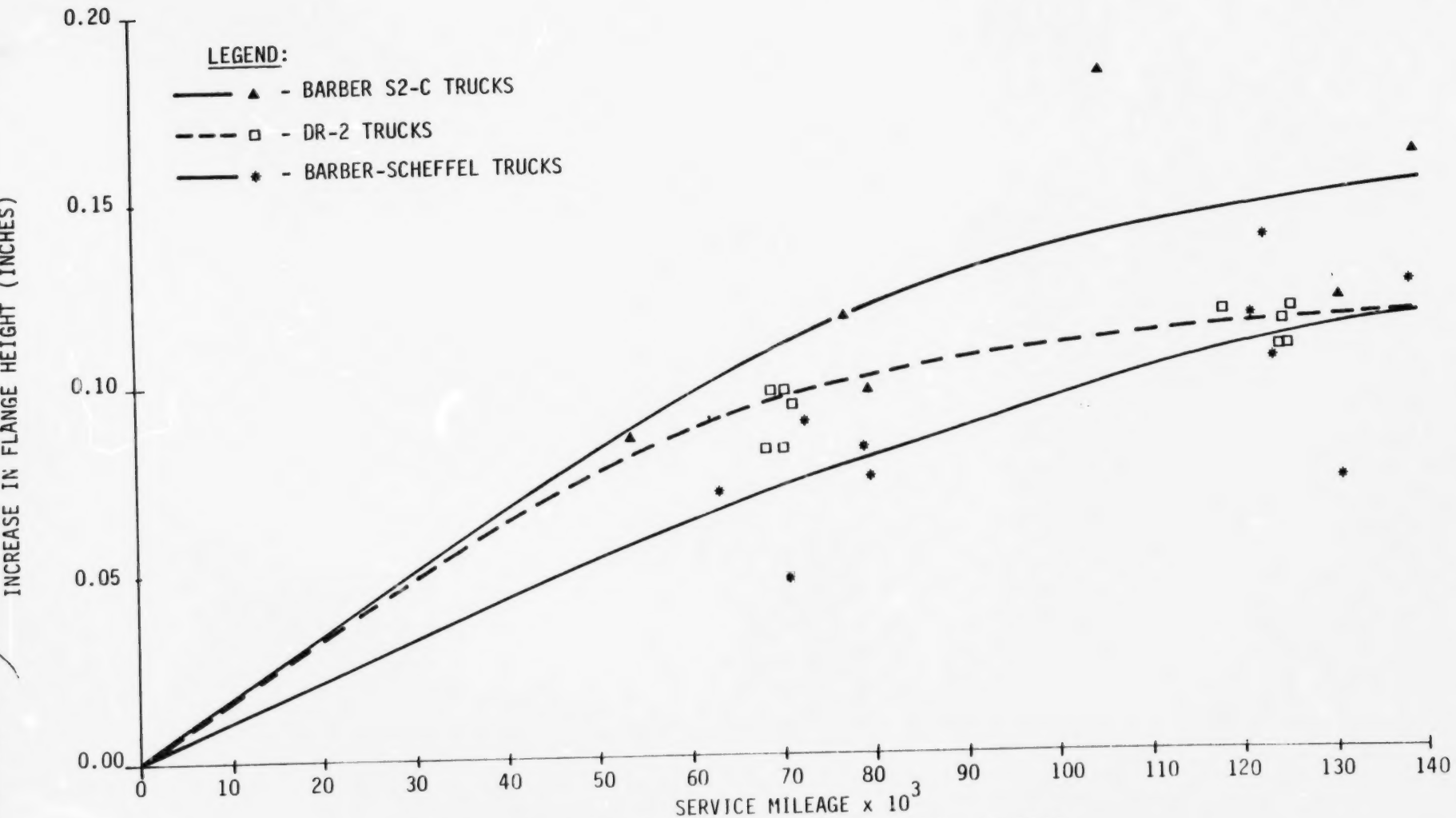


FIG. 7 : INCREASE IN WHEEL FLANGE HEIGHT VERSUS MILEAGE

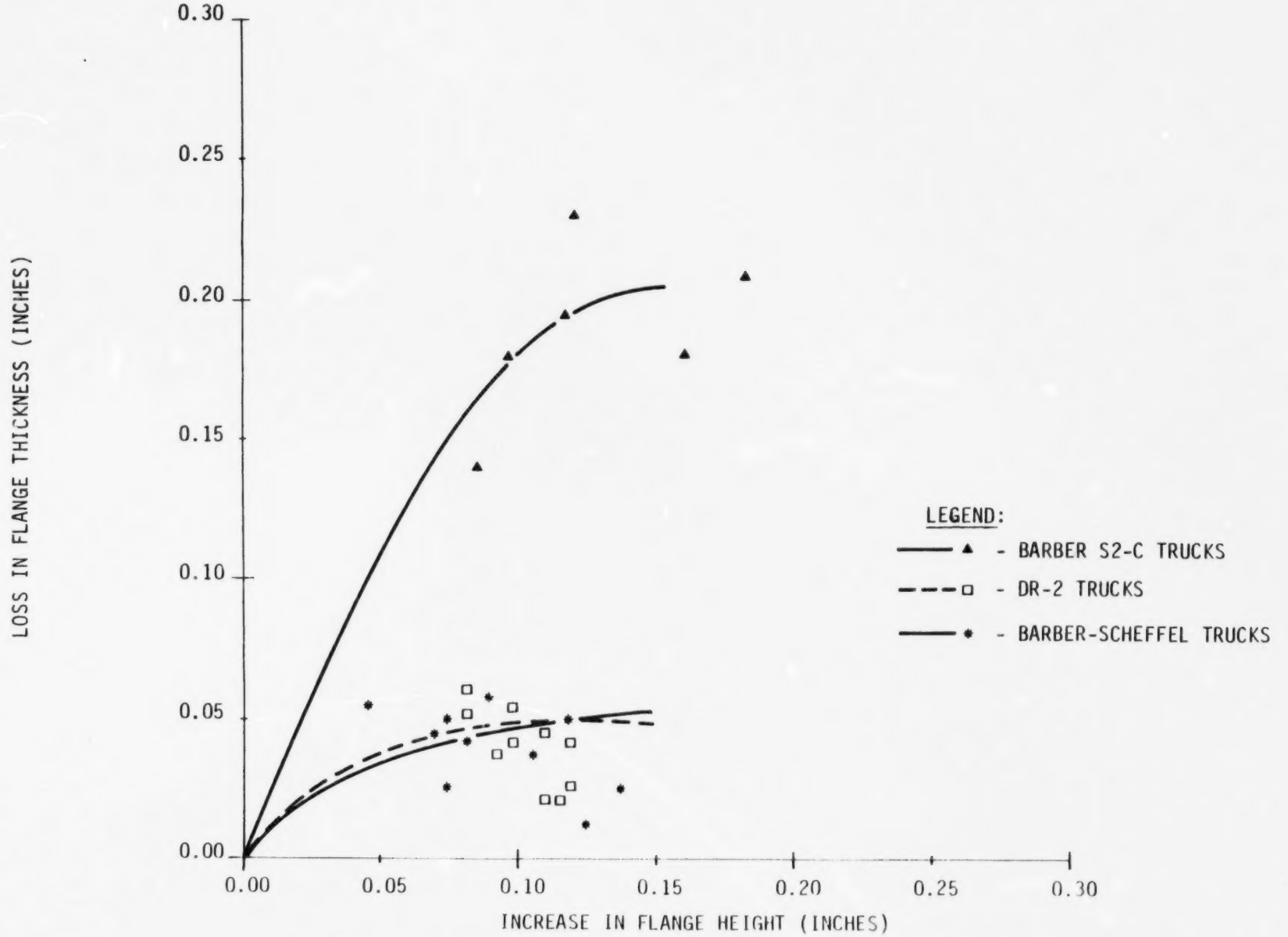


FIG. 8 : LOSS OF WHEEL FLANGE THICKNESS VERSUS INCREASE IN FLANGE HEIGHT

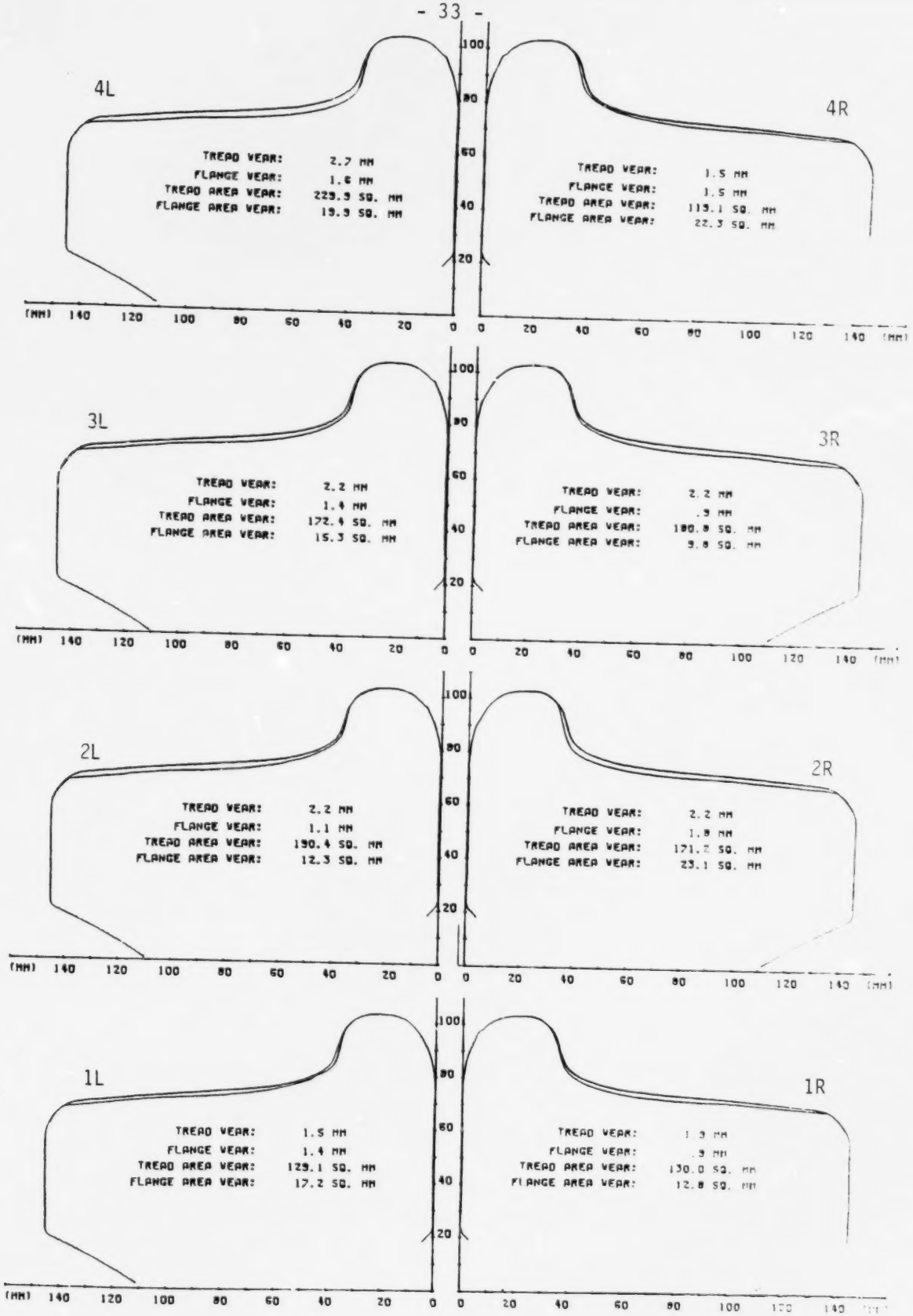

4L
TREAD WEAR: 2.7 MM
FLANGE WEAR: 1.6 MM
TREAD AREA WEAR: 229.9 SQ. MM
FLANGE AREA WEAR: 19.9 SQ. MM
4R
TREAD WEAR: 1.5 MM
FLANGE WEAR: 1.5 MM
TREAD AREA WEAR: 119.1 SQ. MM
FLANGE AREA WEAR: 22.3 SQ. MM
3L
TREAD WEAR: 2.2 MM
FLANGE WEAR: 1.4 MM
TREAD AREA WEAR: 172.4 SQ. MM
FLANGE AREA WEAR: 15.3 SQ. MM
3R
TREAD WEAR: 2.2 MM
FLANGE WEAR: .9 MM
TREAD AREA WEAR: 180.9 SQ. MM
FLANGE AREA WEAR: 9.8 SQ. MM
2L
TREAD WEAR: 2.2 MM
FLANGE WEAR: 1.1 MM
TREAD AREA WEAR: 190.4 SQ. MM
FLANGE AREA WEAR: 12.3 SQ. MM
2R
TREAD WEAR: 2.2 MM
FLANGE WEAR: 1.8 MM
TREAD AREA WEAR: 171.2 SQ. MM
FLANGE AREA WEAR: 23.1 SQ. MM
1L
TREAD WEAR: 1.5 MM
FLANGE WEAR: 1.4 MM
TREAD AREA WEAR: 129.1 SQ. MM
FLANGE AREA WEAR: 17.2 SQ. MM
1R
TREAD WEAR: 1.9 MM
FLANGE WEAR: .9 MM
TREAD AREA WEAR: 130.0 SQ. MM
FLANGE AREA WEAR: 12.8 SQ. MM
(MM) 140 120 100 80 60 40 20 0
0 20 40 60 80 100 120 140 (MM)

FIG. 9: WHEEL PROFILES ON CAR CP 352439 EQUIPPED WITH BARBER-SCHEFFEL TRUCKS AFTER 123,000 MILES OF REVENUE SERVICE

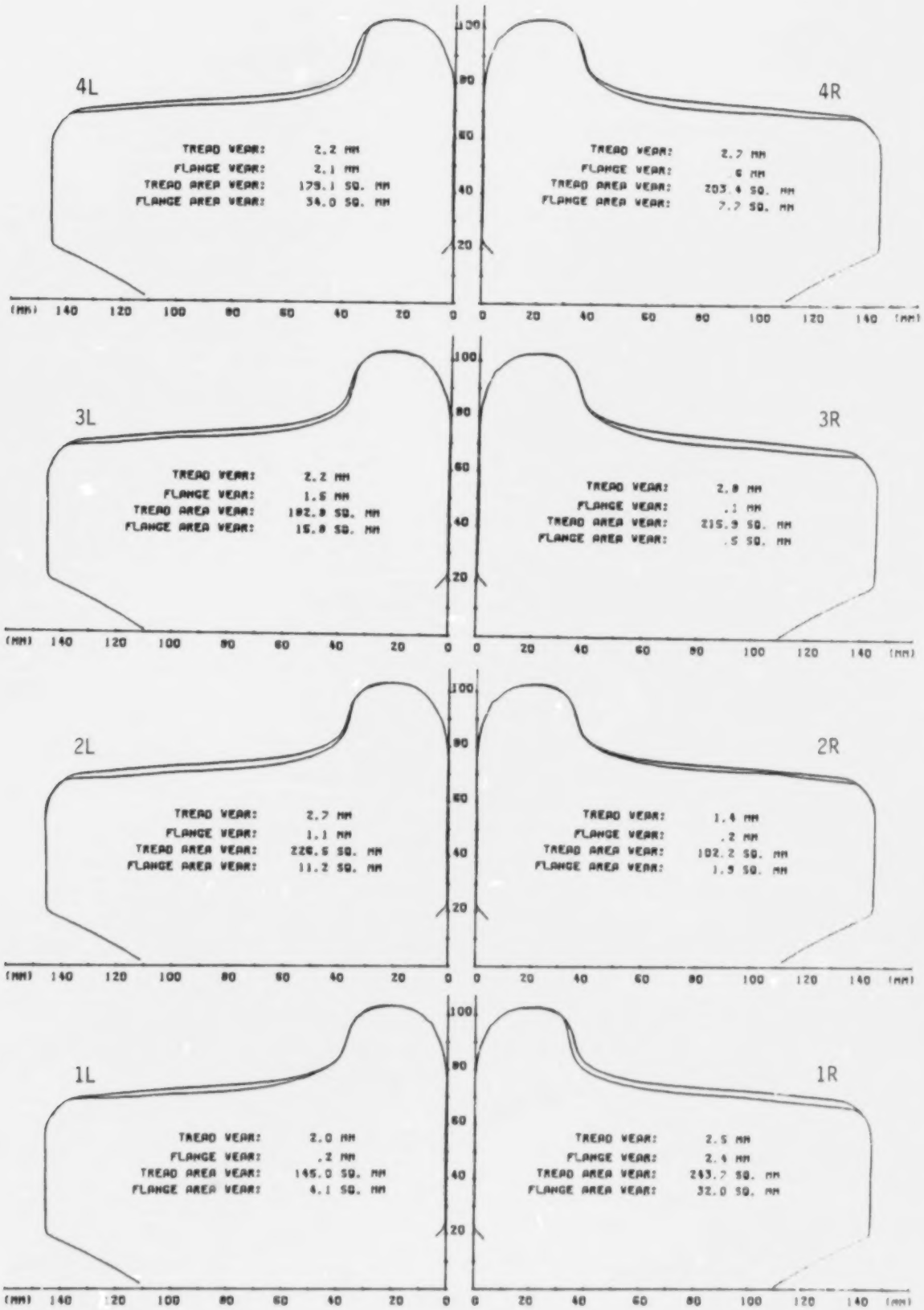

4L
TREAD WEAR: 2.2 MM
FLANGE WEAR: 2.1 MM
TREAD AREA WEAR: 179.1 SQ. MM
FLANGE AREA WEAR: 34.0 SQ. MM
4R
TREAD WEAR: 2.7 MM
FLANGE WEAR: 6 MM
TREAD AREA WEAR: 203.4 SQ. MM
FLANGE AREA WEAR: 7.7 SQ. MM
3L
TREAD WEAR: 2.2 MM
FLANGE WEAR: 1.5 MM
TREAD AREA WEAR: 182.9 SQ. MM
FLANGE AREA WEAR: 15.0 SQ. MM
3R
TREAD WEAR: 2.8 MM
FLANGE WEAR: .1 MM
TREAD AREA WEAR: 215.9 SQ. MM
FLANGE AREA WEAR: .5 SQ. MM
2L
TREAD WEAR: 2.7 MM
FLANGE WEAR: 1.1 MM
TREAD AREA WEAR: 226.5 SQ. MM
FLANGE AREA WEAR: 11.2 SQ. MM
2R
TREAD WEAR: 1.4 MM
FLANGE WEAR: .2 MM
TREAD AREA WEAR: 102.2 SQ. MM
FLANGE AREA WEAR: 1.9 SQ. MM
1L
TREAD WEAR: 2.0 MM
FLANGE WEAR: .2 MM
TREAD AREA WEAR: 145.0 SQ. MM
FLANGE AREA WEAR: 4.1 SQ. MM
1R
TREAD WEAR: 2.5 MM
FLANGE WEAR: 2.4 MM
TREAD AREA WEAR: 243.2 SQ. MM
FLANGE AREA WEAR: 32.0 SQ. MM
(MM) 140 120 100 80 60 40 20 0
0 20 40 60 80 100 120 140 (MM)

FIG. 10: WHEEL PROFILES ON CAR CP 352440 EQUIPPED WITH BARBER-SCHEFFEL TRUCKS AFTER 138,000 MILES OF REVENUE SERVICE

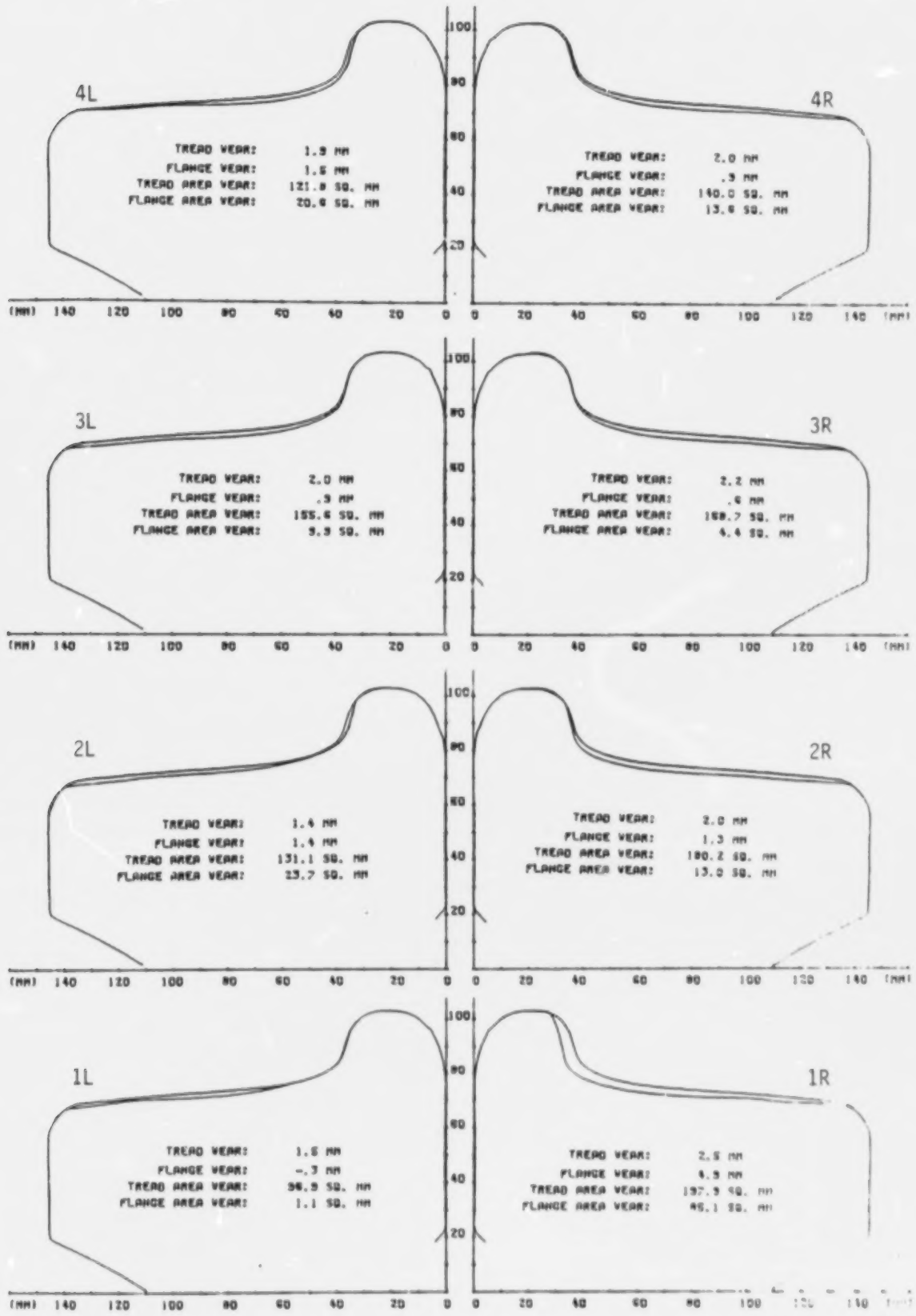

4L
TREAD WEAR: 1.9 MM
FLANGE WEAR: 1.5 MM
TREAD AREA WEAR: 121.8 SQ. MM
FLANGE AREA WEAR: 20.6 SQ. MM
4R
TREAD WEAR: 2.0 MM
FLANGE WEAR: .9 MM
TREAD AREA WEAR: 140.0 SQ. MM
FLANGE AREA WEAR: 13.6 SQ. MM
3L
TREAD WEAR: 2.0 MM
FLANGE WEAR: .9 MM
TREAD AREA WEAR: 155.6 SQ. MM
FLANGE AREA WEAR: 9.9 SQ. MM
3R
TREAD WEAR: 2.2 MM
FLANGE WEAR: .6 MM
TREAD AREA WEAR: 169.7 SQ. MM
FLANGE AREA WEAR: 6.4 SQ. MM
2L
TREAD WEAR: 1.4 MM
FLANGE WEAR: 1.4 MM
TREAD AREA WEAR: 131.1 SQ. MM
FLANGE AREA WEAR: 23.7 SQ. MM
2R
TREAD WEAR: 2.0 MM
FLANGE WEAR: 1.3 MM
TREAD AREA WEAR: 180.2 SQ. MM
FLANGE AREA WEAR: 13.0 SQ. MM
1L
TREAD WEAR: 1.6 MM
FLANGE WEAR: -.3 MM
TREAD AREA WEAR: 96.9 SQ. MM
FLANGE AREA WEAR: 1.1 SQ. MM
1R
TREAD WEAR: 2.5 MM
FLANGE WEAR: 4.5 MM
TREAD AREA WEAR: 197.9 SQ. MM
FLANGE AREA WEAR: 46.1 SQ. MM
(MM) 140 120 100 80 60 40 20 0
0 20 40 60 80 100 120 140 (MM)

FIG. 11: WHEEL PROFILES ON CAR CP 352441 EQUIPPED WITH BARBER-SCHEFFEL TRUCKS AFTER 121,000 MILES OF REVENUE SERVICE

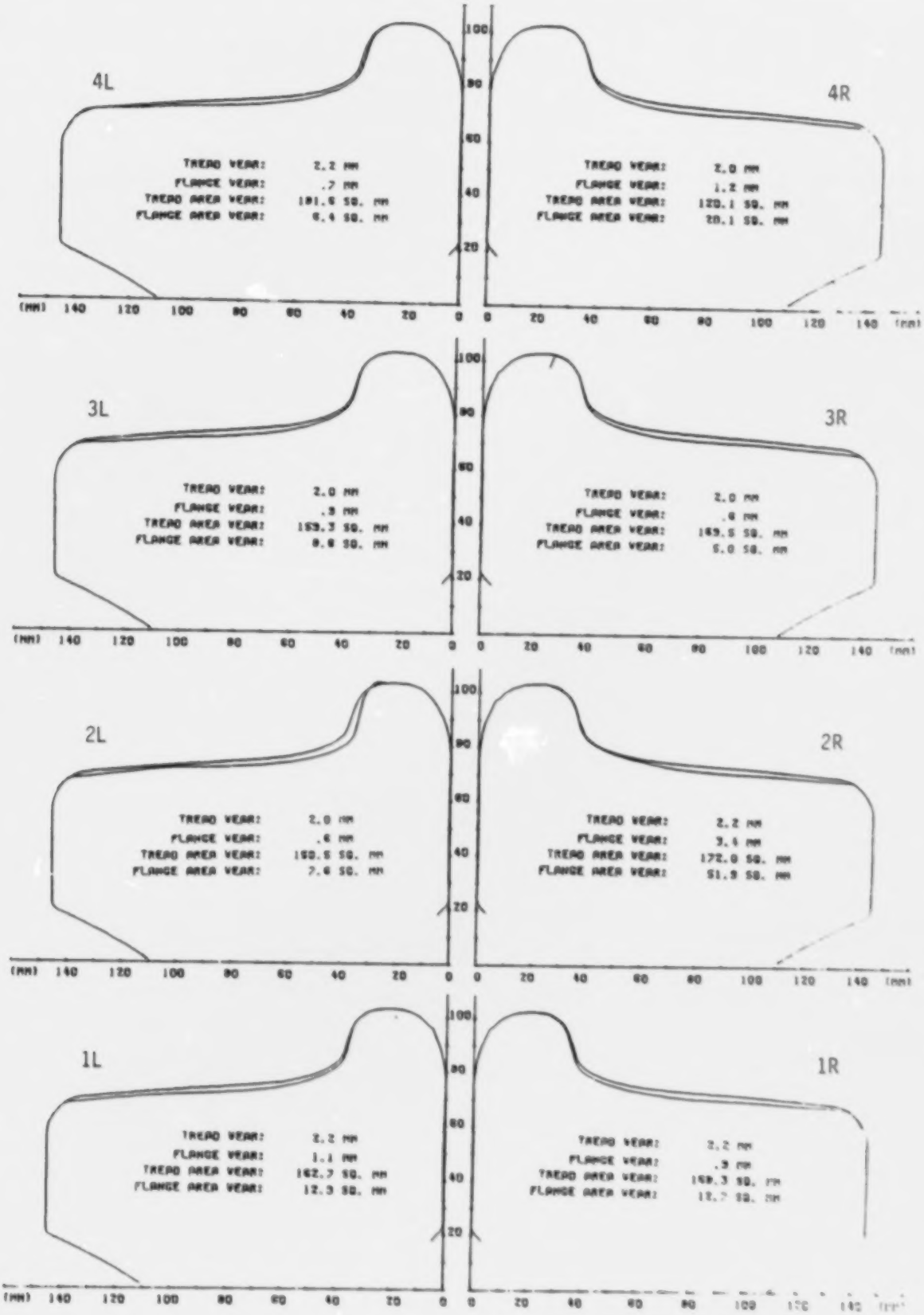

4L
TREAD WEAR: 2.2 MM
FLANGE WEAR: .7 MM
TREAD AREA WEAR: 181.6 SQ. MM
FLANGE AREA WEAR: 8.4 SQ. MM
4R
TREAD WEAR: 2.0 MM
FLANGE WEAR: 1.2 MM
TREAD AREA WEAR: 120.1 SQ. MM
FLANGE AREA WEAR: 20.1 SQ. MM
3L
TREAD WEAR: 2.0 MM
FLANGE WEAR: .3 MM
TREAD AREA WEAR: 153.3 SQ. MM
FLANGE AREA WEAR: 8.8 SQ. MM
3R
TREAD WEAR: 2.0 MM
FLANGE WEAR: .6 MM
TREAD AREA WEAR: 169.5 SQ. MM
FLANGE AREA WEAR: 5.0 SQ. MM
2L
TREAD WEAR: 2.0 MM
FLANGE WEAR: .6 MM
TREAD AREA WEAR: 150.5 SQ. MM
FLANGE AREA WEAR: 7.6 SQ. MM
2R
TREAD WEAR: 2.2 MM
FLANGE WEAR: 3.4 MM
TREAD AREA WEAR: 172.0 SQ. MM
FLANGE AREA WEAR: 51.9 SQ. MM
1L
TREAD WEAR: 2.2 MM
FLANGE WEAR: 1.1 MM
TREAD AREA WEAR: 162.7 SQ. MM
FLANGE AREA WEAR: 12.3 SQ. MM
1R
TREAD WEAR: 2.2 MM
FLANGE WEAR: .3 MM
TREAD AREA WEAR: 169.3 SQ. MM
FLANGE AREA WEAR: 12.7 SQ. MM
(MM) 140 120 100 80 60 40 20 0
0 20 40 60 80 100 120 140 (MM)

FIG. 12: WHEEL PROFILES ON CAR CP 352442 EQUIPPED WITH BARBER-SCHEFFEL TRUCKS AFTER 131,000 MILES OF REVENUE SERVICE

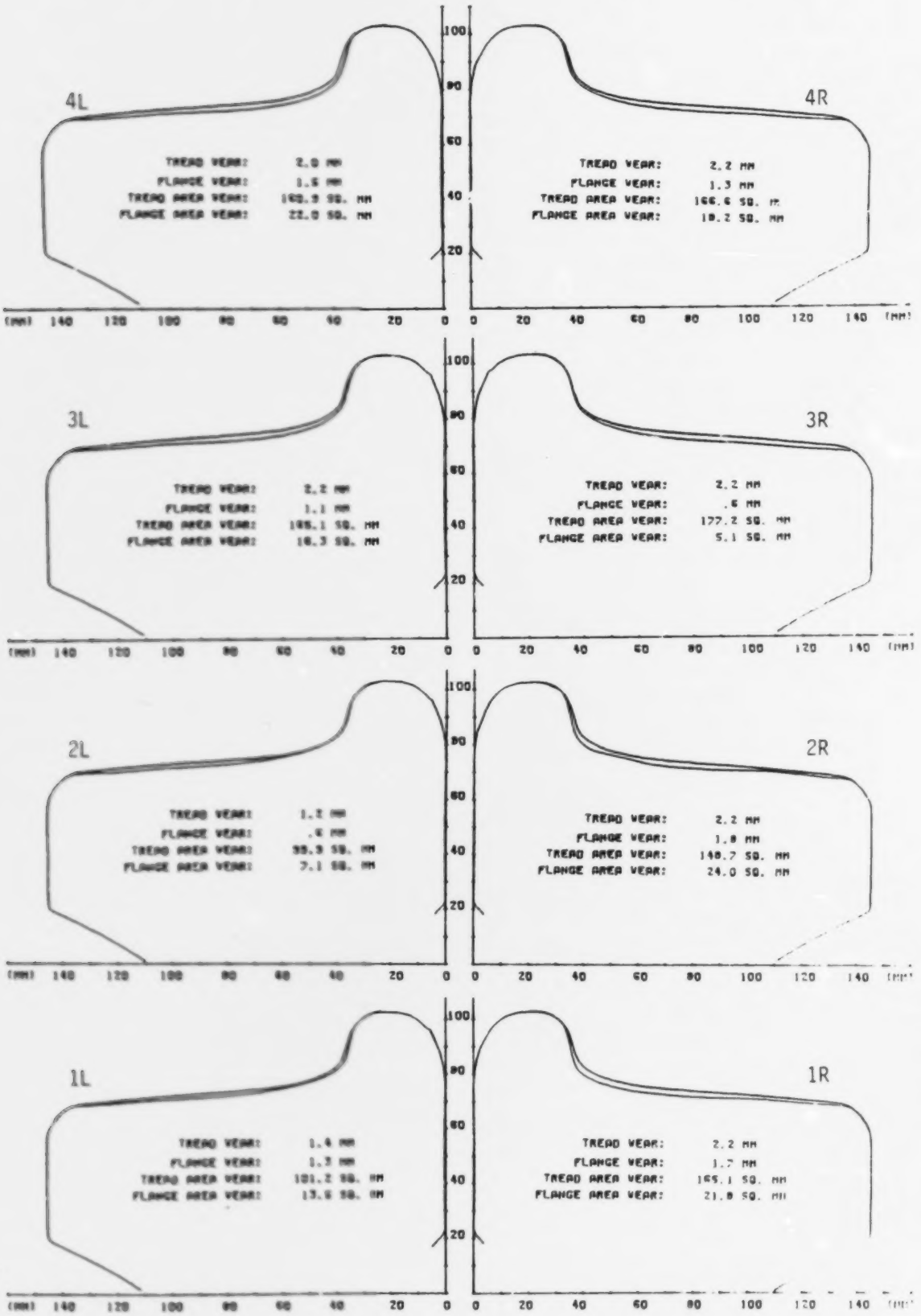


FIG. 13: WHEEL PROFILES ON CAR CP 352443 EQUIPPED WITH BARBER-SCHEFFEL TRUCKS AFTER 122,000 MILES OF REVENUE SERVICE

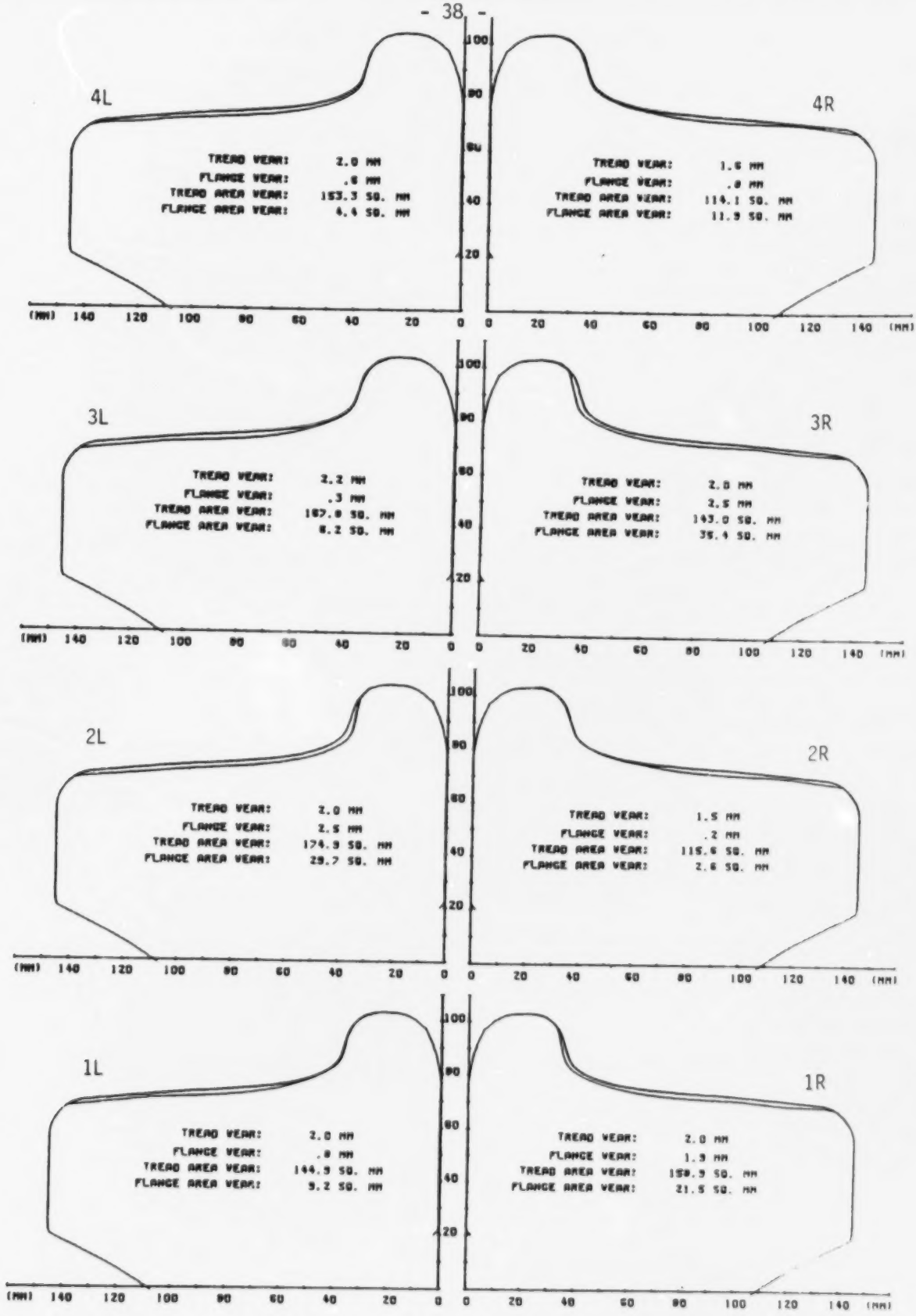

4L
TREAD WEAR: 2.0 MM
FLANGE WEAR: .6 MM
TREAD AREA WEAR: 153.3 SQ. MM
FLANGE AREA WEAR: 4.4 SQ. MM
4R
TREAD WEAR: 1.6 MM
FLANGE WEAR: .0 MM
TREAD AREA WEAR: 114.1 SQ. MM
FLANGE AREA WEAR: 11.9 SQ. MM
3L
TREAD WEAR: 2.2 MM
FLANGE WEAR: .3 MM
TREAD AREA WEAR: 167.0 SQ. MM
FLANGE AREA WEAR: 8.2 SQ. MM
3R
TREAD WEAR: 2.0 MM
FLANGE WEAR: 2.5 MM
TREAD AREA WEAR: 143.0 SQ. MM
FLANGE AREA WEAR: 35.4 SQ. MM
2L
TREAD WEAR: 2.0 MM
FLANGE WEAR: 2.5 MM
TREAD AREA WEAR: 174.9 SQ. MM
FLANGE AREA WEAR: 29.7 SQ. MM
2R
TREAD WEAR: 1.5 MM
FLANGE WEAR: .2 MM
TREAD AREA WEAR: 115.6 SQ. MM
FLANGE AREA WEAR: 2.6 SQ. MM
1L
TREAD WEAR: 2.0 MM
FLANGE WEAR: .0 MM
TREAD AREA WEAR: 144.5 SQ. MM
FLANGE AREA WEAR: 9.2 SQ. MM
1R
TREAD WEAR: 2.0 MM
FLANGE WEAR: 1.3 MM
TREAD AREA WEAR: 159.9 SQ. MM
FLANGE AREA WEAR: 21.5 SQ. MM
(MM) 140 120 100 80 60 40 20 0
0 20 40 60 80 100 120 140 (MM)

FIG. 14: WHEEL PROFILES ON CAR CP 352849 EQUIPPED WITH DR-2 TRUCKS AFTER 118,500 MILES OF REVENUE SERVICE

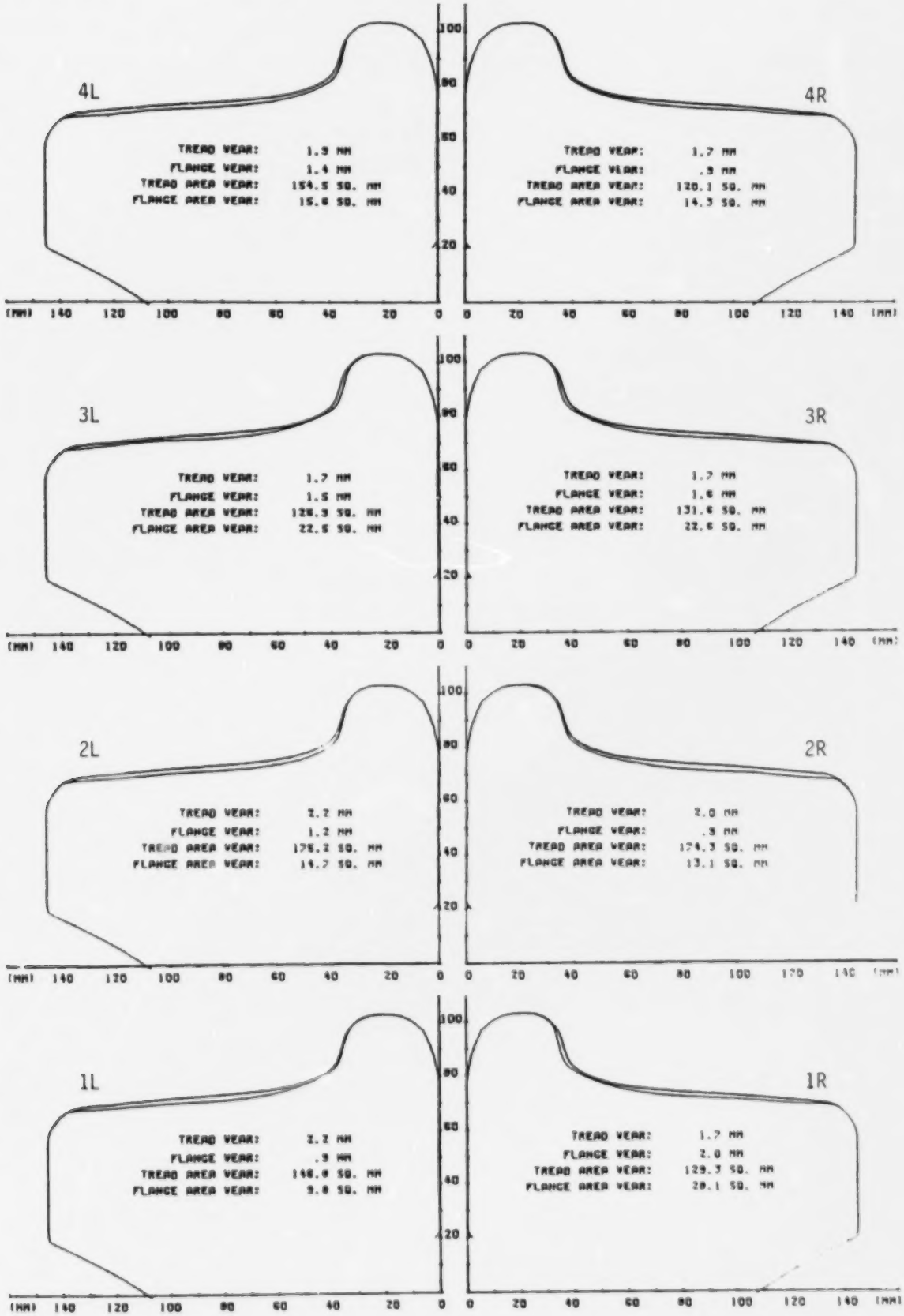

4L
TREAD WEAR: 1.9 MM
FLANGE WEAR: 1.4 MM
TREAD AREA WEAR: 154.5 SQ. MM
FLANGE AREA WEAR: 15.6 SQ. MM
4R
TREAD WEAR: 1.7 MM
FLANGE WEAR: .9 MM
TREAD AREA WEAR: 120.1 SQ. MM
FLANGE AREA WEAR: 14.3 SQ. MM
3L
TREAD WEAR: 1.7 MM
FLANGE WEAR: 1.5 MM
TREAD AREA WEAR: 126.9 SQ. MM
FLANGE AREA WEAR: 22.5 SQ. MM
3R
TREAD WEAR: 1.7 MM
FLANGE WEAR: 1.6 MM
TREAD AREA WEAR: 131.6 SQ. MM
FLANGE AREA WEAR: 22.6 SQ. MM
2L
TREAD WEAR: 2.2 MM
FLANGE WEAR: 1.2 MM
TREAD AREA WEAR: 175.2 SQ. MM
FLANGE AREA WEAR: 14.7 SQ. MM
2R
TREAD WEAR: 2.0 MM
FLANGE WEAR: .5 MM
TREAD AREA WEAR: 174.3 SQ. MM
FLANGE AREA WEAR: 13.1 SQ. MM
1L
TREAD WEAR: 2.2 MM
FLANGE WEAR: .9 MM
TREAD AREA WEAR: 148.0 SQ. MM
FLANGE AREA WEAR: 9.8 SQ. MM
1R
TREAD WEAR: 1.7 MM
FLANGE WEAR: 2.0 MM
TREAD AREA WEAR: 129.3 SQ. MM
FLANGE AREA WEAR: 20.1 SQ. MM
(MM) 140 120 100 80 60 40 20 0
0 20 40 60 80 100 120 140 (MM)

FIG. 15: WHEEL PROFILES ON CAR CP 352850 EQUIPPED WITH DR-2 TRUCKS AFTER 124,000 MILES OF REVENUE SERVICE

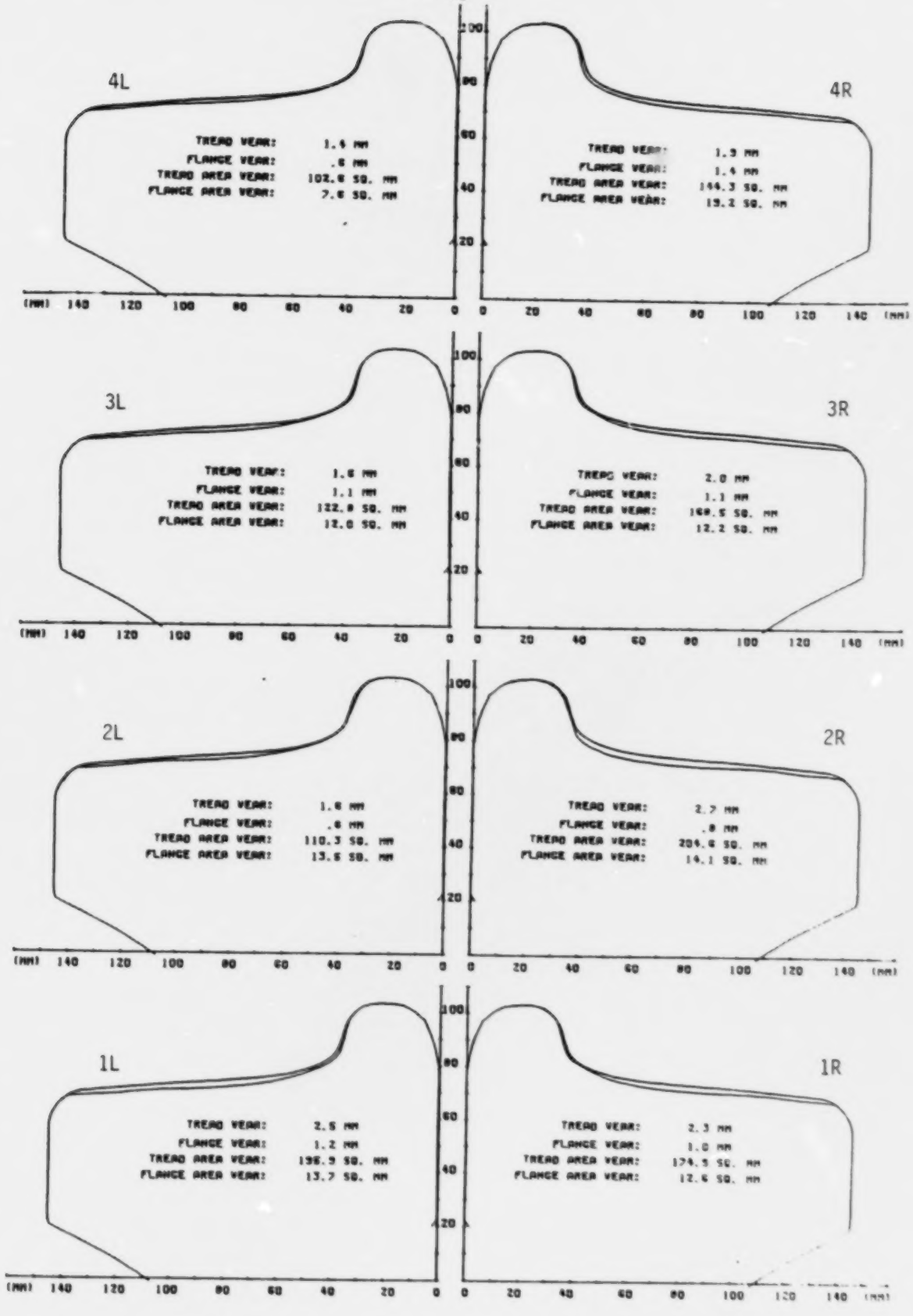

4L
TREAD WEAR: 1.4 MM
FLANGE WEAR: .6 MM
TREAD AREA WEAR: 102.6 SQ. MM
FLANGE AREA WEAR: 7.6 SQ. MM
4R
TREAD WEAR: 1.3 MM
FLANGE WEAR: 1.4 MM
TREAD AREA WEAR: 144.3 SQ. MM
FLANGE AREA WEAR: 19.2 SQ. MM
3L
TREAD WEAR: 1.6 MM
FLANGE WEAR: 1.1 MM
TREAD AREA WEAR: 122.8 SQ. MM
FLANGE AREA WEAR: 12.0 SQ. MM
3R
TREAD WEAR: 2.0 MM
FLANGE WEAR: 1.1 MM
TREAD AREA WEAR: 169.5 SQ. MM
FLANGE AREA WEAR: 12.2 SQ. MM
2L
TREAD WEAR: 1.6 MM
FLANGE WEAR: .6 MM
TREAD AREA WEAR: 110.3 SQ. MM
FLANGE AREA WEAR: 13.5 SQ. MM
2R
TREAD WEAR: 2.7 MM
FLANGE WEAR: .9 MM
TREAD AREA WEAR: 204.6 SQ. MM
FLANGE AREA WEAR: 14.1 SQ. MM
1L
TREAD WEAR: 2.5 MM
FLANGE WEAR: 1.2 MM
TREAD AREA WEAR: 196.9 SQ. MM
FLANGE AREA WEAR: 13.7 SQ. MM
1R
TREAD WEAR: 2.3 MM
FLANGE WEAR: 1.0 MM
TREAD AREA WEAR: 174.5 SQ. MM
FLANGE AREA WEAR: 12.6 SQ. MM

FIG. 16: WHEEL PROFILES ON CAR CP 352851 EQUIPPED WITH DR-2 TRUCKS AFTER 124,500 MILES OF REVENUE SERVICE

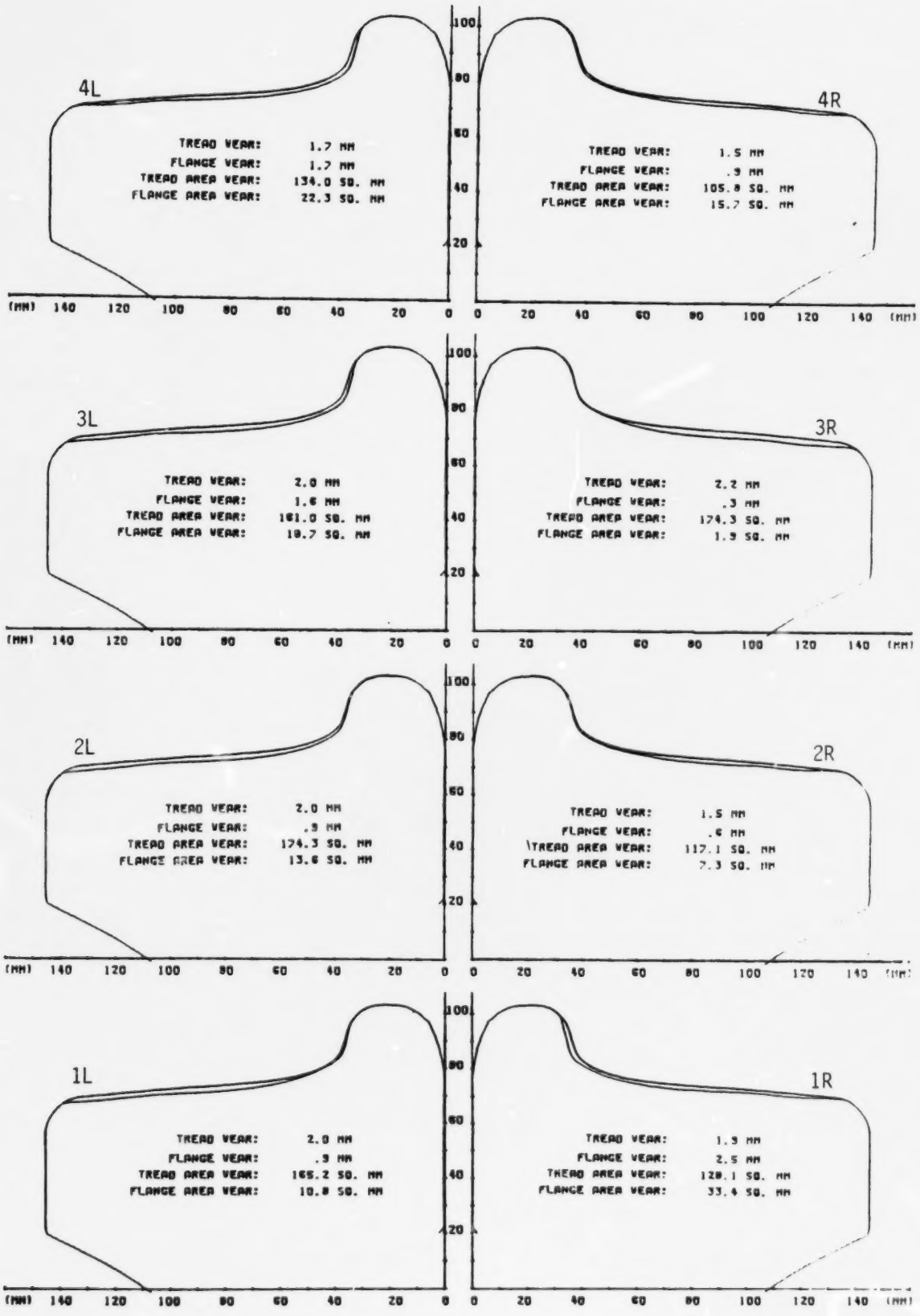

4L
TREAD WEAR: 1.7 MM
FLANGE WEAR: 1.7 MM
TREAD AREA WEAR: 134.0 SQ. MM
FLANGE AREA WEAR: 22.3 SQ. MM
4R
TREAD WEAR: 1.5 MM
FLANGE WEAR: .9 MM
TREAD AREA WEAR: 105.8 SQ. MM
FLANGE AREA WEAR: 15.7 SQ. MM
3L
TREAD WEAR: 2.0 MM
FLANGE WEAR: 1.6 MM
TREAD AREA WEAR: 161.0 SQ. MM
FLANGE AREA WEAR: 19.7 SQ. MM
3R
TREAD WEAR: 2.2 MM
FLANGE WEAR: .3 MM
TREAD AREA WEAR: 174.3 SQ. MM
FLANGE AREA WEAR: 1.9 SQ. MM
2L
TREAD WEAR: 2.0 MM
FLANGE WEAR: .9 MM
TREAD AREA WEAR: 174.3 SQ. MM
FLANGE AREA WEAR: 13.6 SQ. MM
2R
TREAD WEAR: 1.5 MM
FLANGE WEAR: .6 MM
TREAD AREA WEAR: 117.1 SQ. MM
FLANGE AREA WEAR: 7.3 SQ. MM
1L
TREAD WEAR: 2.0 MM
FLANGE WEAR: .9 MM
TREAD AREA WEAR: 165.2 SQ. MM
FLANGE AREA WEAR: 10.8 SQ. MM
1R
TREAD WEAR: 1.9 MM
FLANGE WEAR: 2.5 MM
TREAD AREA WEAR: 128.1 SQ. MM
FLANGE AREA WEAR: 33.4 SQ. MM
(MM) 140 120 100 80 60 40 20 0
0 20 40 60 80 100 120 140 (MM)

FIG. 17: WHEEL PROFILES ON CAR CP 352852 EQUIPPED WITH DR-2 TRUCKS AFTER 124,500 MILES OF REVENUE SERVICE

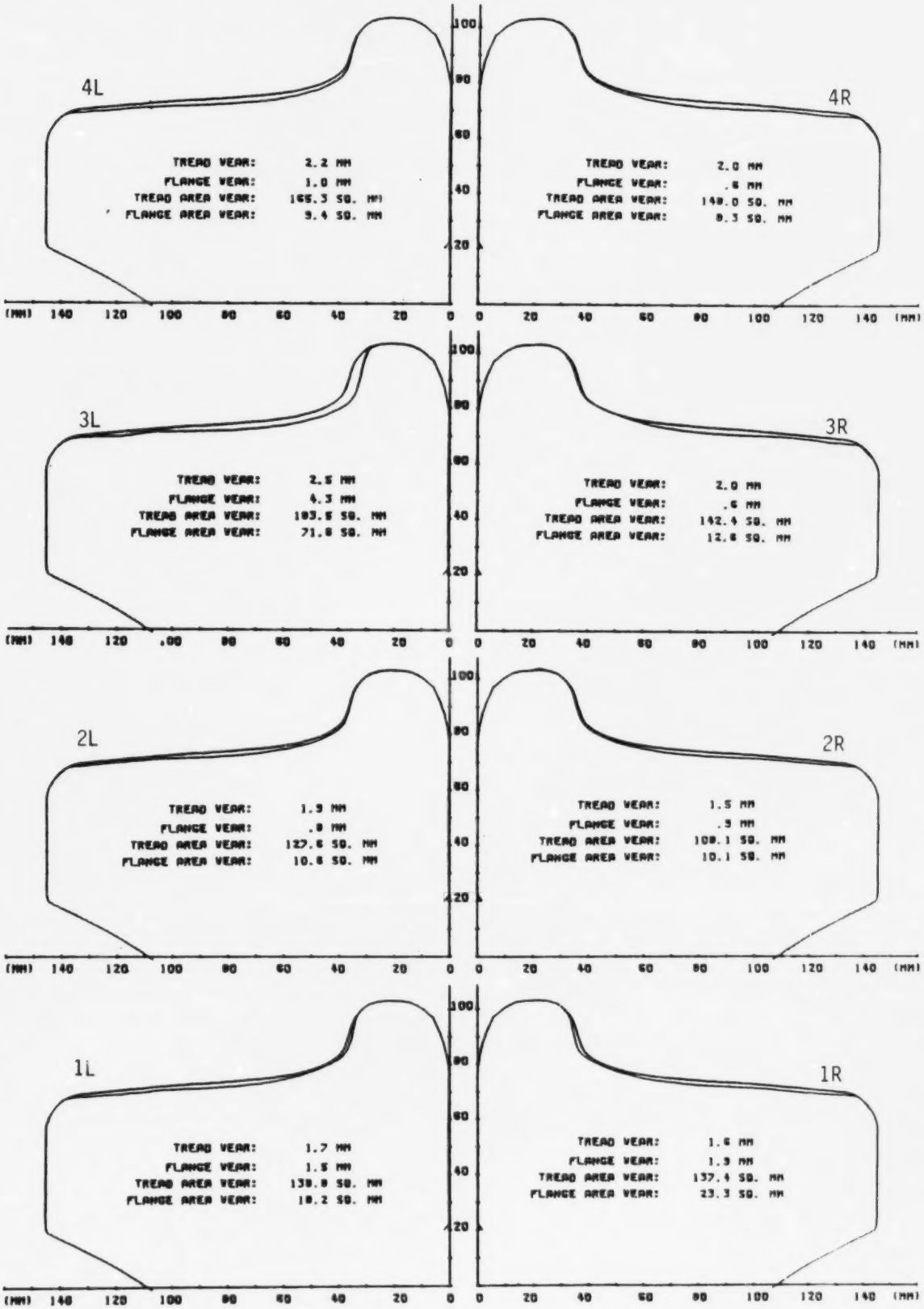
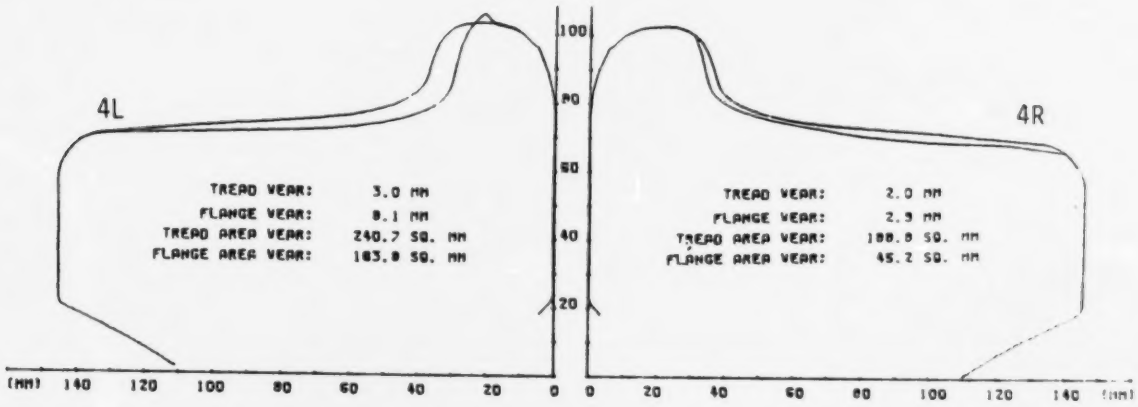

4L
TREAD WEAR: 2.2 MM
FLANGE WEAR: 1.0 MM
TREAD AREA WEAR: 165.3 SQ. MM
FLANGE AREA WEAR: 9.4 SQ. MM
4R
TREAD WEAR: 2.0 MM
FLANGE WEAR: .6 MM
TREAD AREA WEAR: 149.0 SQ. MM
FLANGE AREA WEAR: 8.3 SQ. MM
3L
TREAD WEAR: 2.5 MM
FLANGE WEAR: 4.3 MM
TREAD AREA WEAR: 183.5 SQ. MM
FLANGE AREA WEAR: 21.8 SQ. MM
3R
TREAD WEAR: 2.0 MM
FLANGE WEAR: .6 MM
TREAD AREA WEAR: 142.4 SQ. MM
FLANGE AREA WEAR: 12.6 SQ. MM
2L
TREAD WEAR: 1.9 MM
FLANGE WEAR: .8 MM
TREAD AREA WEAR: 127.6 SQ. MM
FLANGE AREA WEAR: 10.6 SQ. MM
2R
TREAD WEAR: 1.5 MM
FLANGE WEAR: .5 MM
TREAD AREA WEAR: 108.1 SQ. MM
FLANGE AREA WEAR: 10.1 SQ. MM
1L
TREAD WEAR: 1.7 MM
FLANGE WEAR: 1.5 MM
TREAD AREA WEAR: 138.8 SQ. MM
FLANGE AREA WEAR: 18.2 SQ. MM
1R
TREAD WEAR: 1.6 MM
FLANGE WEAR: 1.9 MM
TREAD AREA WEAR: 137.4 SQ. MM
FLANGE AREA WEAR: 23.3 SQ. MM
(MM) 140 120 100 80 60 40 20 0 0 20 40 60 80 100 120 140 (MM)

FIG. 18: WHEEL PROFILES ON CAR CP 352853 EQUIPPED WITH DR-2 TRUCKS AFTER 125,000 MILES OF REVENUE SERVICE


4L
TREAD WEAR: 3.0 MM
FLANGE WEAR: 8.1 MM
TREAD AREA WEAR: 240.7 SQ. MM
FLANGE AREA WEAR: 103.8 SQ. MM
4R
TREAD WEAR: 2.0 MM
FLANGE WEAR: 2.9 MM
TREAD AREA WEAR: 188.8 SQ. MM
FLANGE AREA WEAR: 45.2 SQ. MM
100
80
60
40
20
(MM) 140 120 100 80 60 40 20 0 0 20 40 60 80 100 120 140 (MM)

ORIGINAL WHEELSET #3 WAS CHANGED OUT AFTER 95,000 MILES

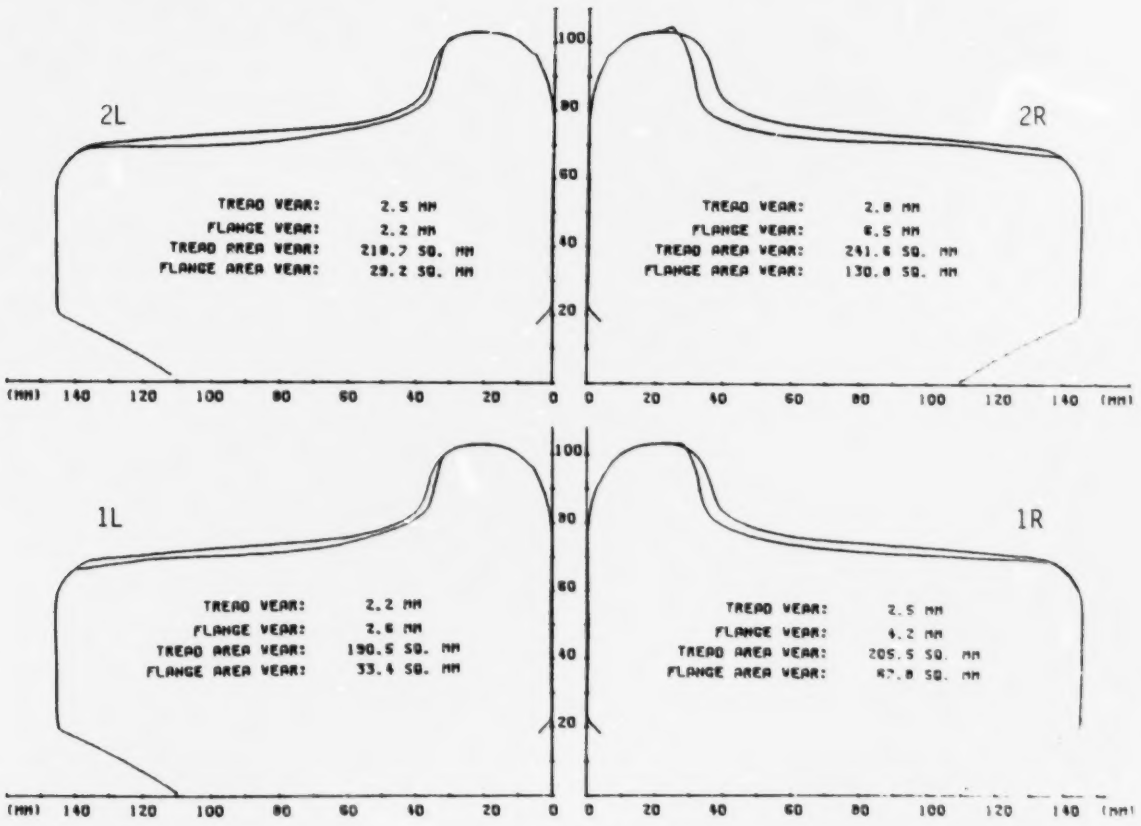

2L
TREAD WEAR: 2.5 MM
FLANGE WEAR: 2.2 MM
TREAD AREA WEAR: 218.7 SQ. MM
FLANGE AREA WEAR: 29.2 SQ. MM
2R
TREAD WEAR: 2.8 MM
FLANGE WEAR: 6.5 MM
TREAD AREA WEAR: 241.6 SQ. MM
FLANGE AREA WEAR: 130.8 SQ. MM
1L
TREAD WEAR: 2.2 MM
FLANGE WEAR: 2.6 MM
TREAD AREA WEAR: 190.5 SQ. MM
FLANGE AREA WEAR: 33.4 SQ. MM
1R
TREAD WEAR: 2.5 MM
FLANGE WEAR: 4.2 MM
TREAD AREA WEAR: 205.5 SQ. MM
FLANGE AREA WEAR: 87.8 SQ. MM
100
80
60
40
20
(MM) 140 120 100 80 60 40 20 0 0 20 40 60 80 100 120 140 (MM)

FIG. 19: WHEEL PROFILES ON CAR CP 351530 EQUIPPED WITH CONVENTIONAL BARBER S2-C TRUCKS AFTER 105,000 MILES OF REVENUE SERVICE

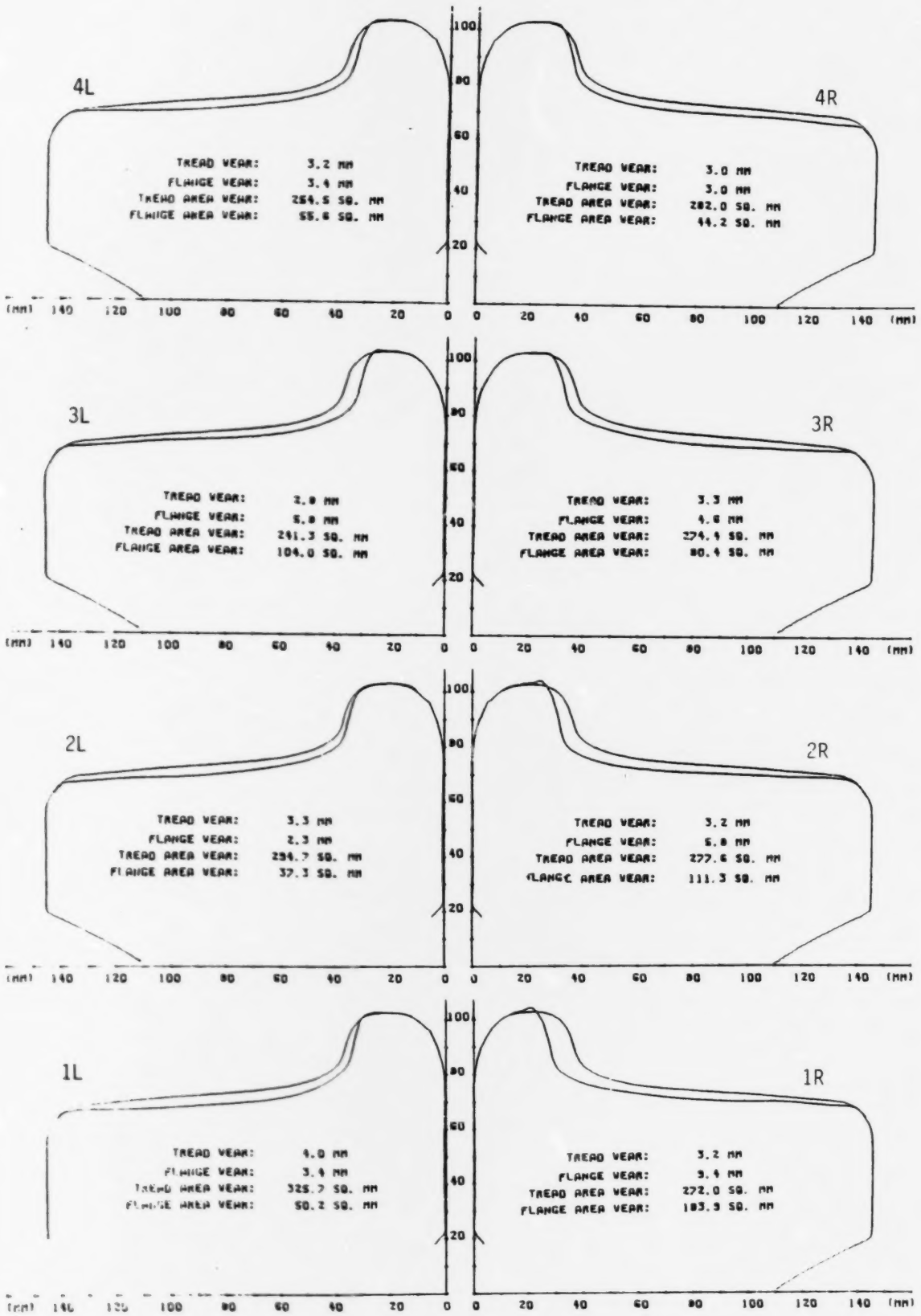
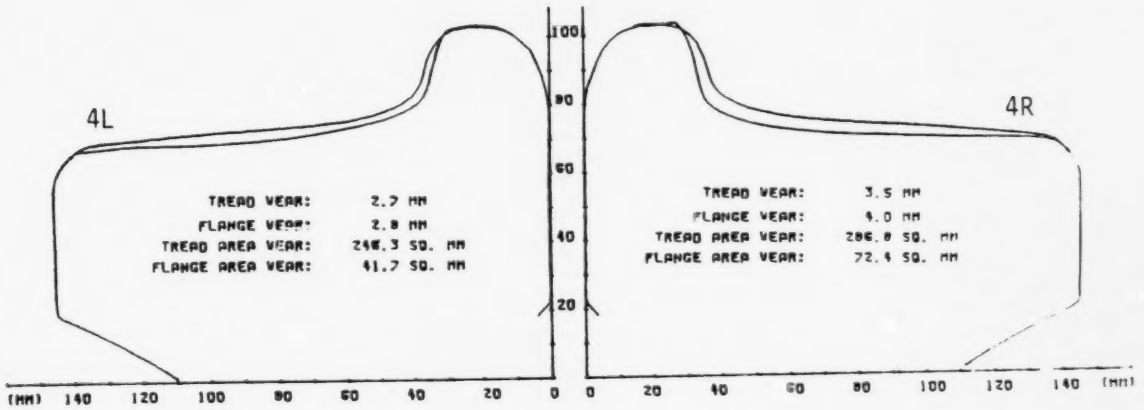


FIG. 20: WHEEL PROFILES ON CAR CP 351581 EQUIPPED WITH CONVENTIONAL BARBER S2-C TRUCKS AFTER 138,000 MILES OF REVENUE SERVICE



ORIGINAL WHEELSET #3 WAS CHANGED OUT AFTER 111,000 MILES

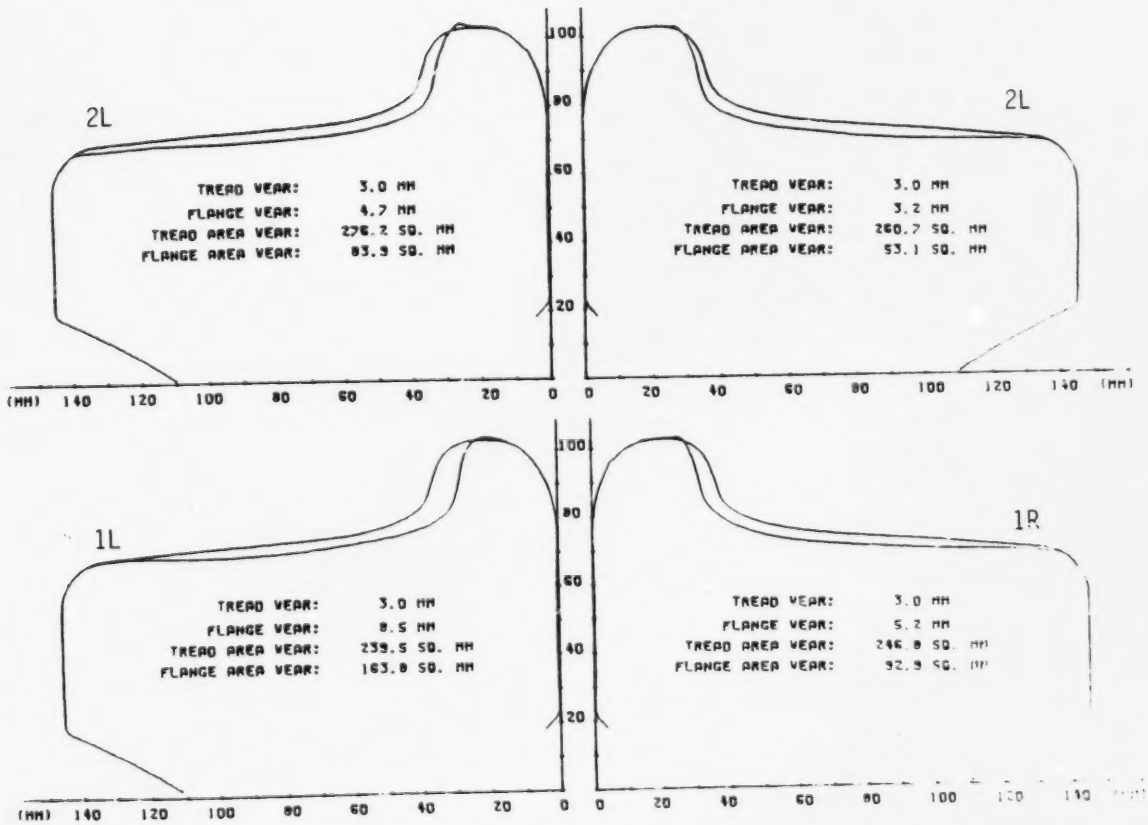

2L
TREAD WEAR: 3.0 MM
FLANGE WEAR: 4.7 MM
TREAD AREA WEAR: 276.2 SQ. MM
FLANGE AREA WEAR: 83.9 SQ. MM
2L
TREAD WEAR: 3.0 MM
FLANGE WEAR: 3.2 MM
TREAD AREA WEAR: 260.7 SQ. MM
FLANGE AREA WEAR: 53.1 SQ. MM
1L
TREAD WEAR: 3.0 MM
FLANGE WEAR: 8.5 MM
TREAD AREA WEAR: 239.5 SQ. MM
FLANGE AREA WEAR: 163.8 SQ. MM
1R
TREAD WEAR: 3.0 MM
FLANGE WEAR: 5.2 MM
TREAD AREA WEAR: 246.8 SQ. MM
FLANGE AREA WEAR: 92.9 SQ. MM
100
80
60
40
20
(MM) 140 120 100 80 60 40 20 0
0 20 40 60 80 100 120 140 (MM)

FIG. 21: WHEEL PROFILES ON CAR CP 351728 EQUIPPED WITH CONVENTIONAL BARBER S2-C TRUCKS AFTER 130,000 MILES OF REVENUE SERVICE

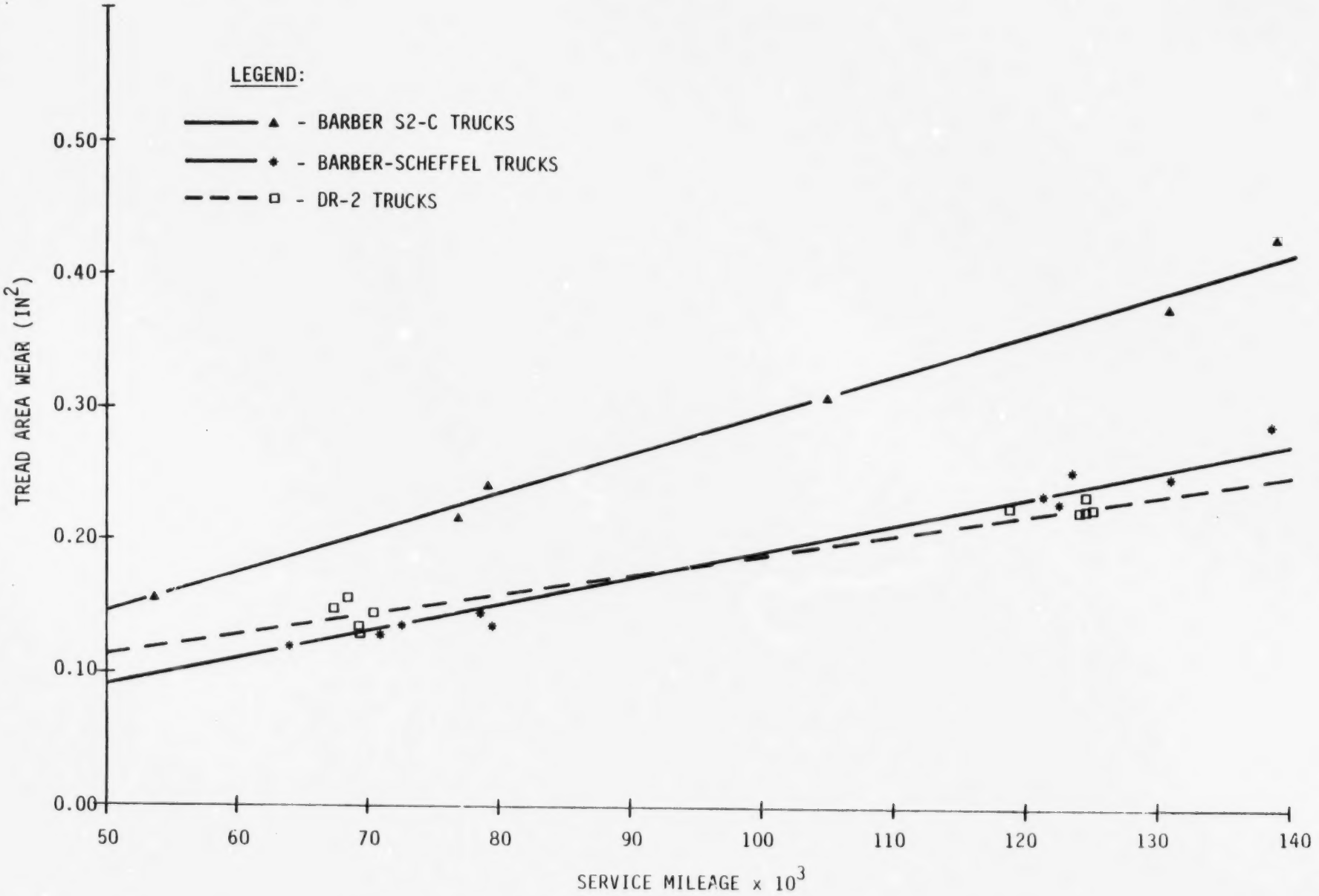


FIG. 22: LOSS OF WHEEL TREAD CROSS-SECTIONAL AREA VERSUS MILEAGE

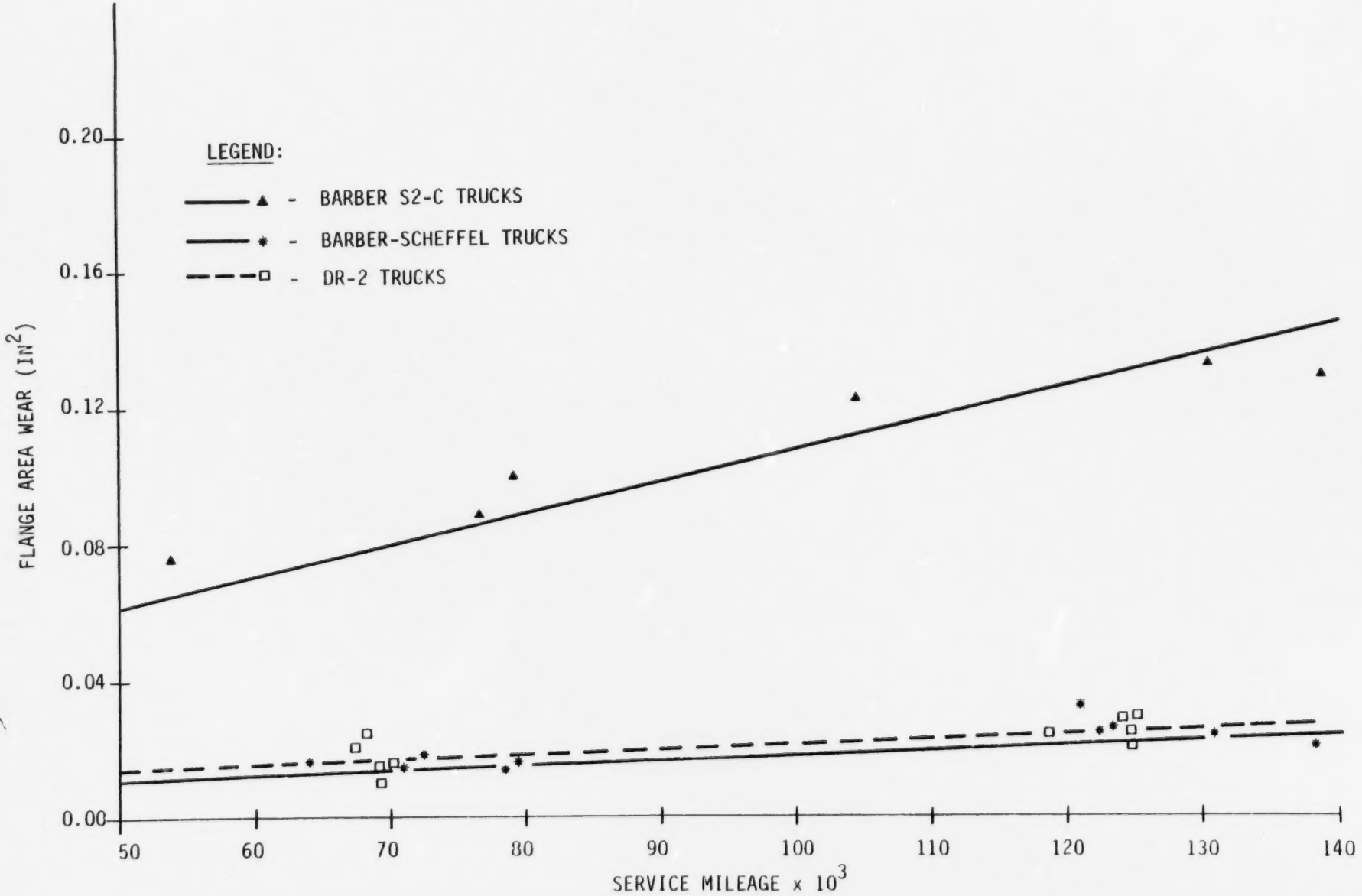
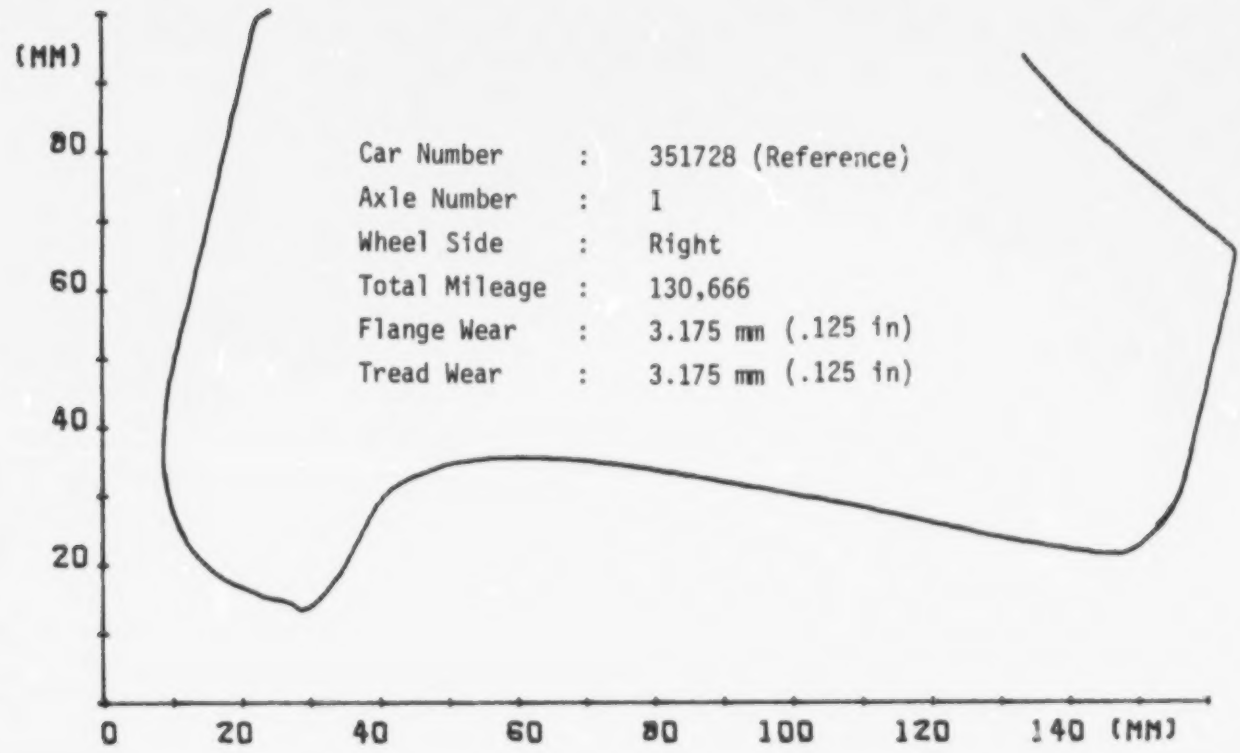


FIG. 23: LOSS OF WHEEL FLANGE CROSS-SECTIONAL AREA VERSUS SERVICE MILEAGE

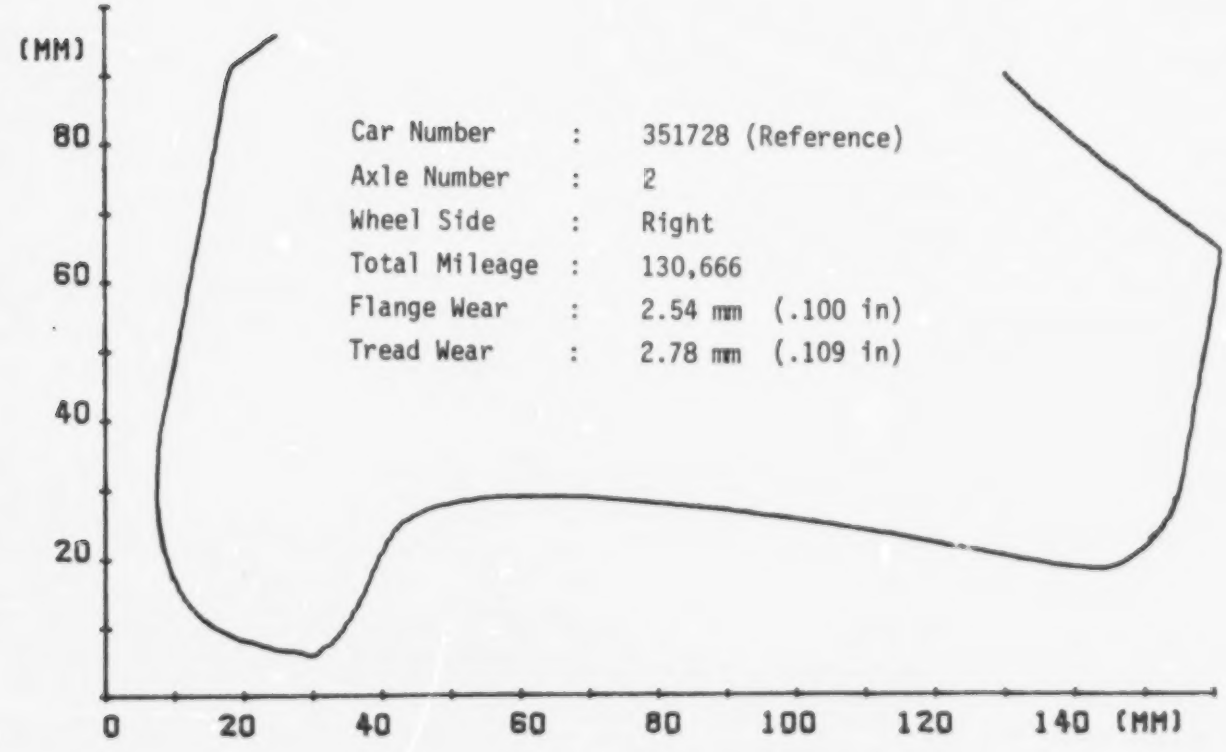
APPENDIX I

SAMPLE WHEEL PROFILES OF TEST CARS
AFTER 130,000 MILES OF REVENUE SERVICE

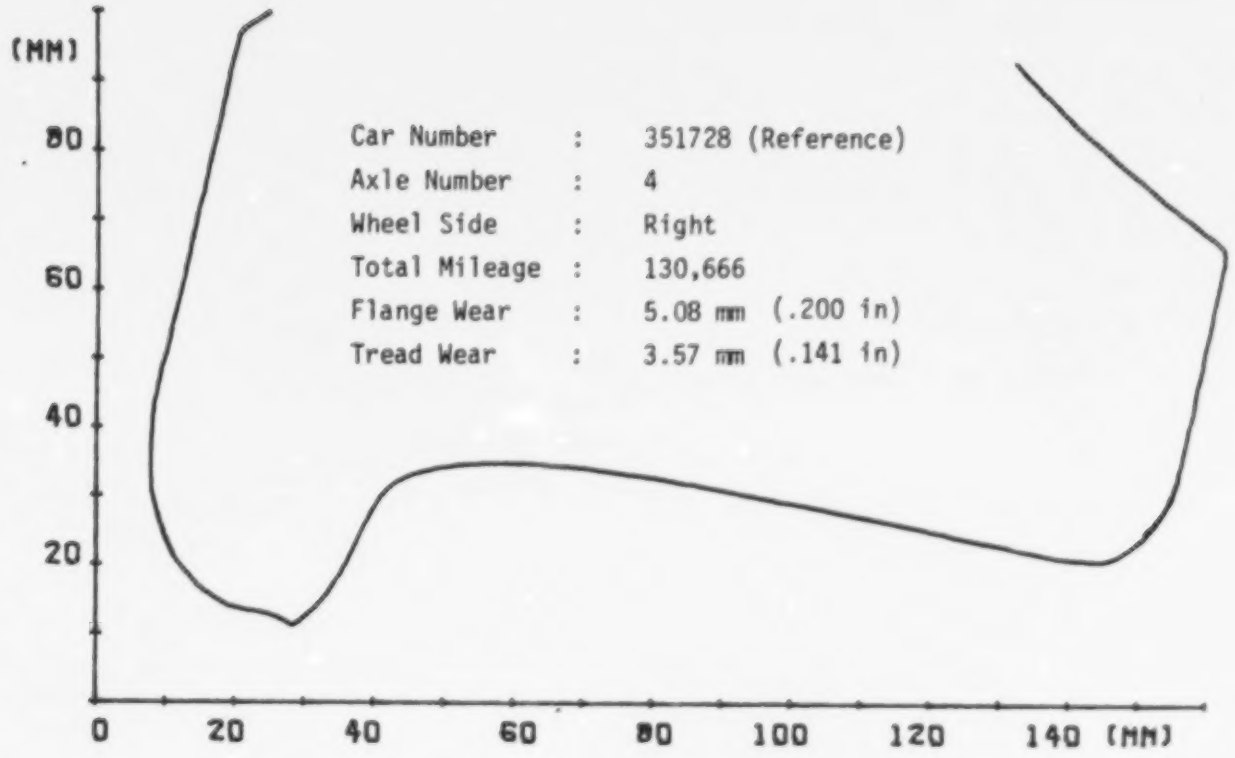
FILE: W10.05.8 ID: 228100



FILE: W10.05.8 ID: 228200

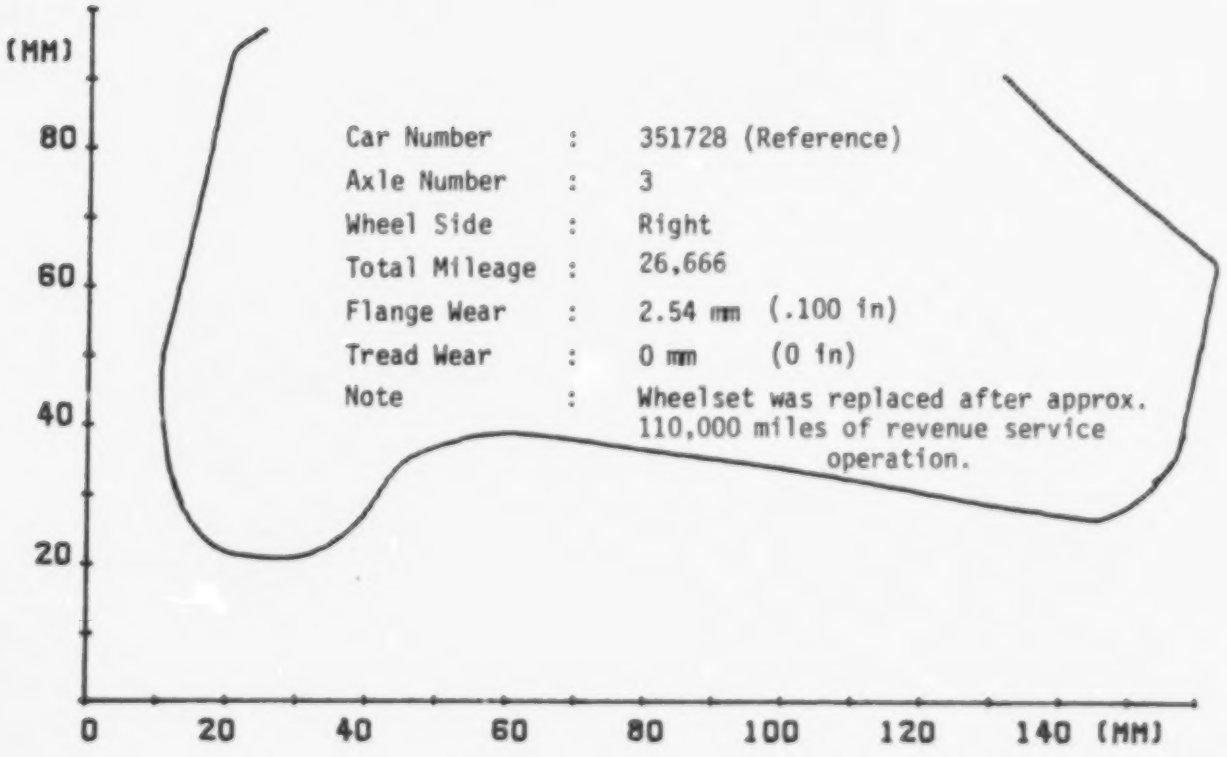


FILE: W10.05.8 ID: 228400



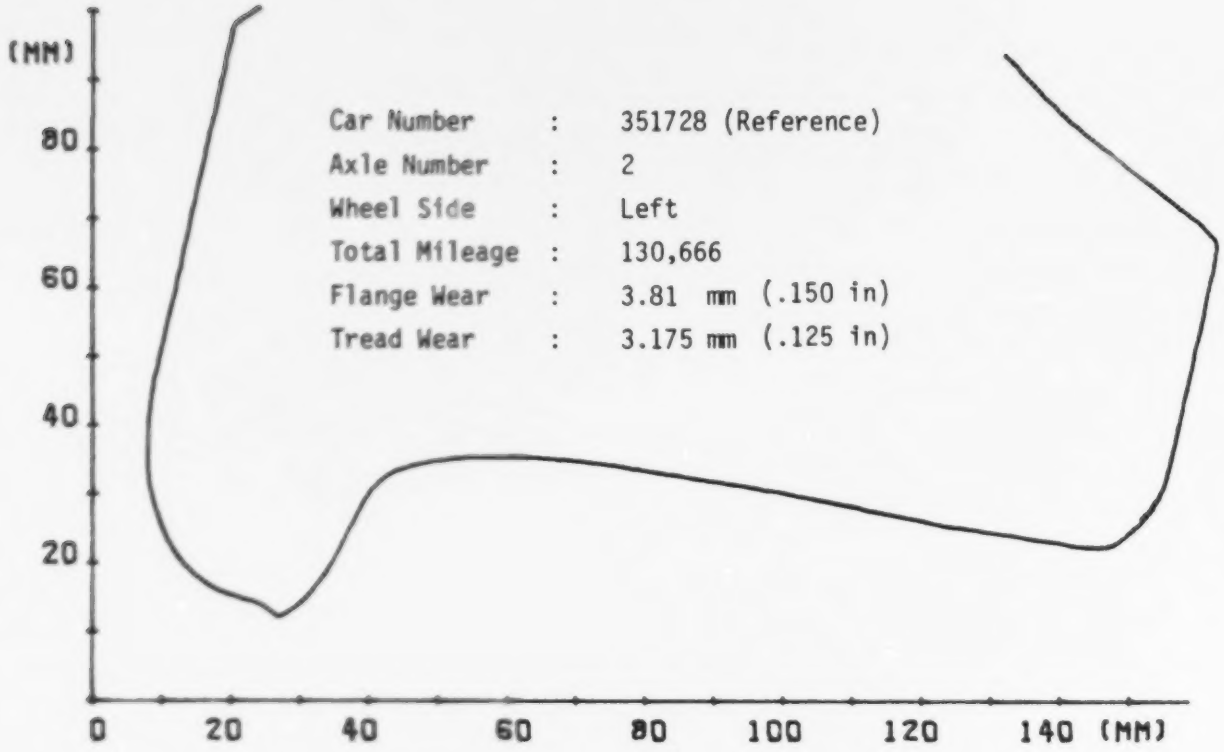
Car Number	:	351728 (Reference)
Axle Number	:	4
Wheel Side	:	Right
Total Mileage	:	130,666
Flange Wear	:	5.08 mm (.200 in)
Tread Wear	:	3.57 mm (.141 in)

FILE: W10.05.8 ID: 228300

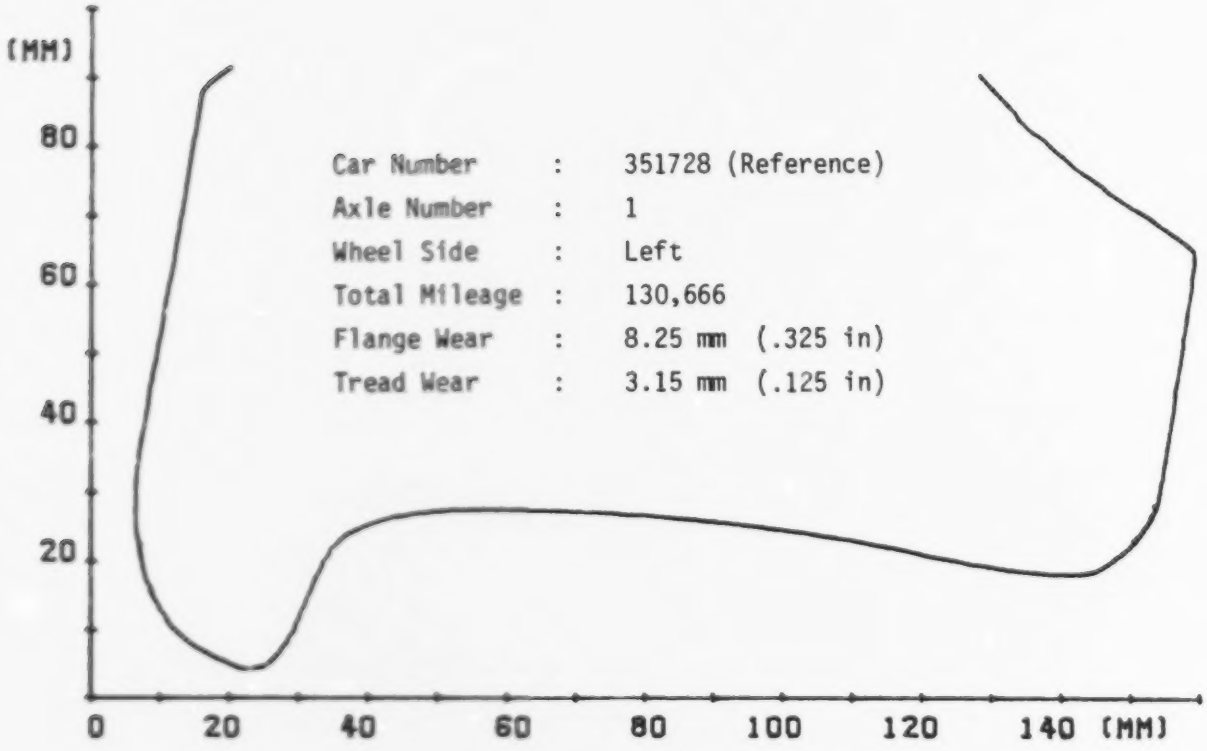


Car Number	:	351728 (Reference)
Axle Number	:	3
Wheel Side	:	Right
Total Mileage	:	26,666
Flange Wear	:	2.54 mm (.100 in)
Tread Wear	:	0 mm (0 in)
Note	:	Wheelset was replaced after approx. 110,000 miles of revenue service operation.

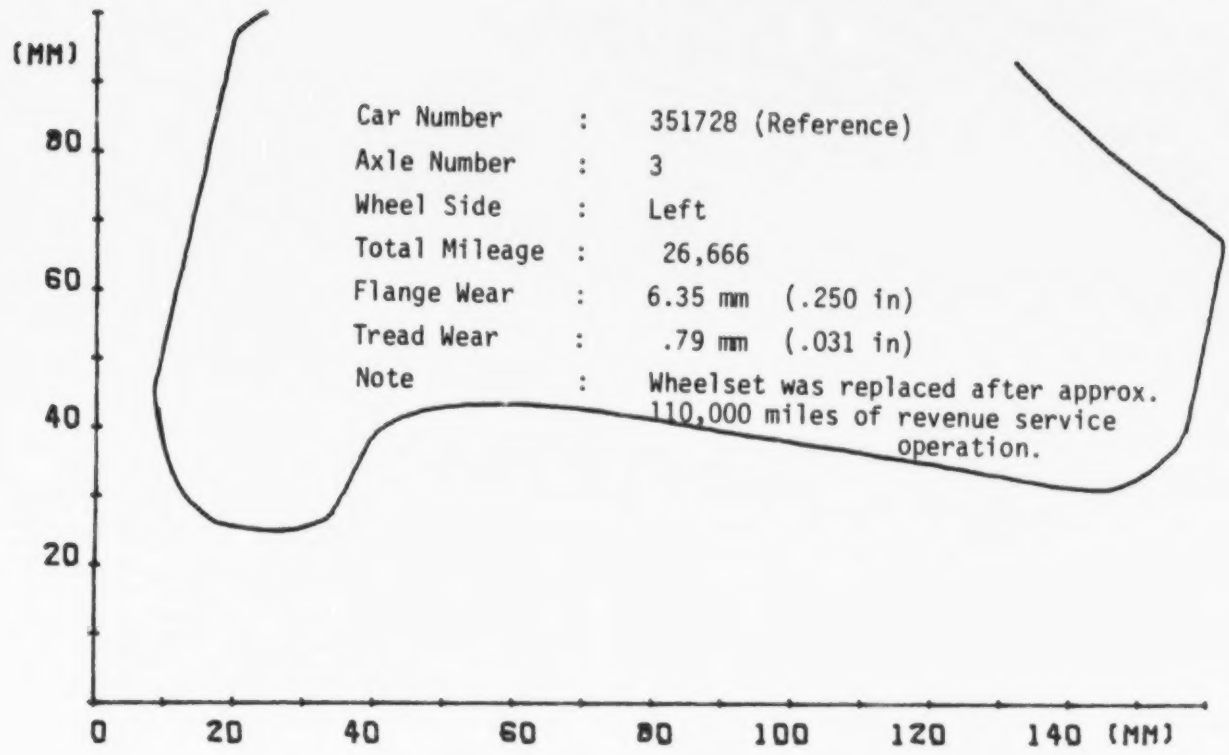
FILE: W10.05.8 ID: 228210



FILE: W10.05.8 ID: 228110

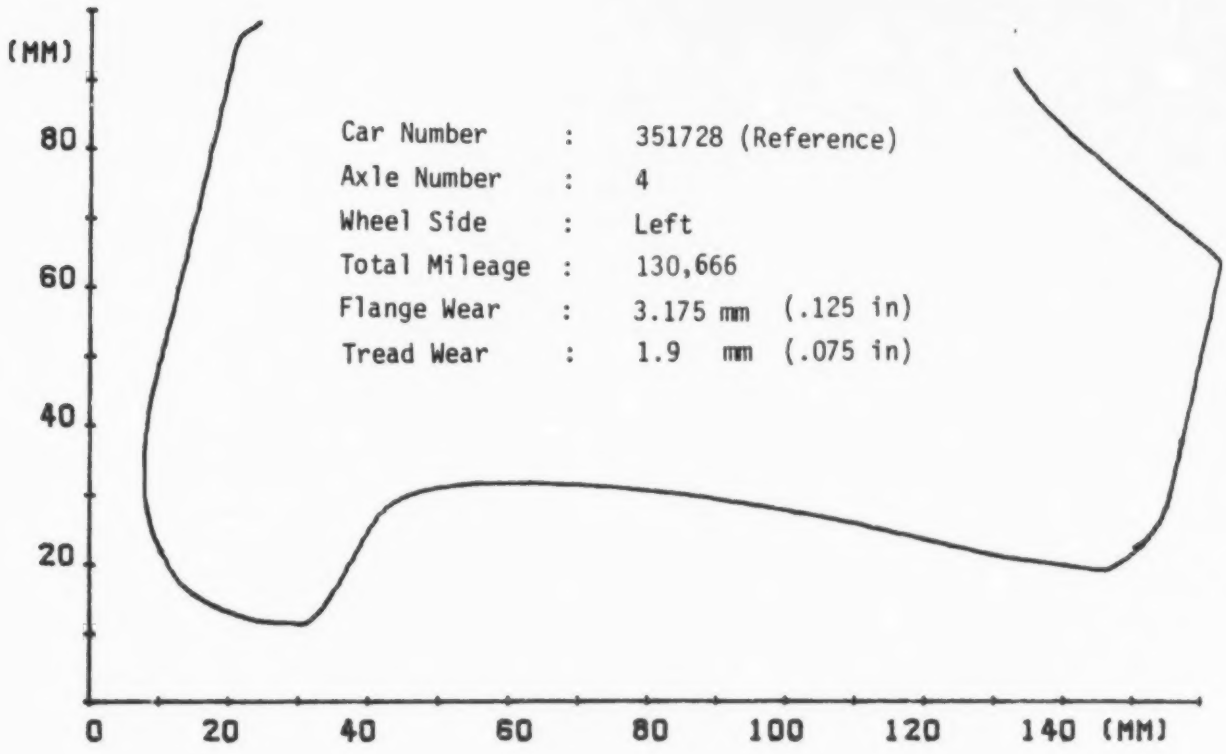


FILE: W10.05.8 ID: 228310

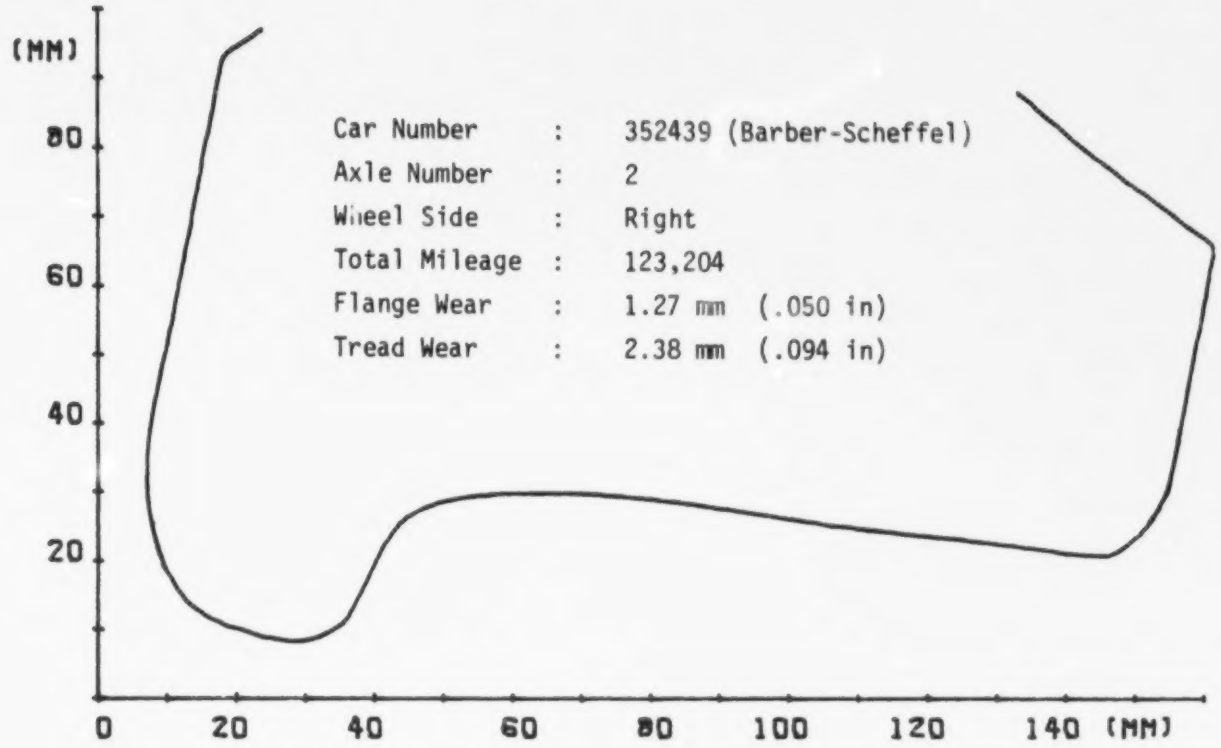


Car Number	:	351728 (Reference)
Axle Number	:	3
Wheel Side	:	Left
Total Mileage	:	26,666
Flange Wear	:	6.35 mm (.250 in)
Tread Wear	:	.79 mm (.031 in)
Note	:	Wheelset was replaced after approx. 110,000 miles of revenue service operation.

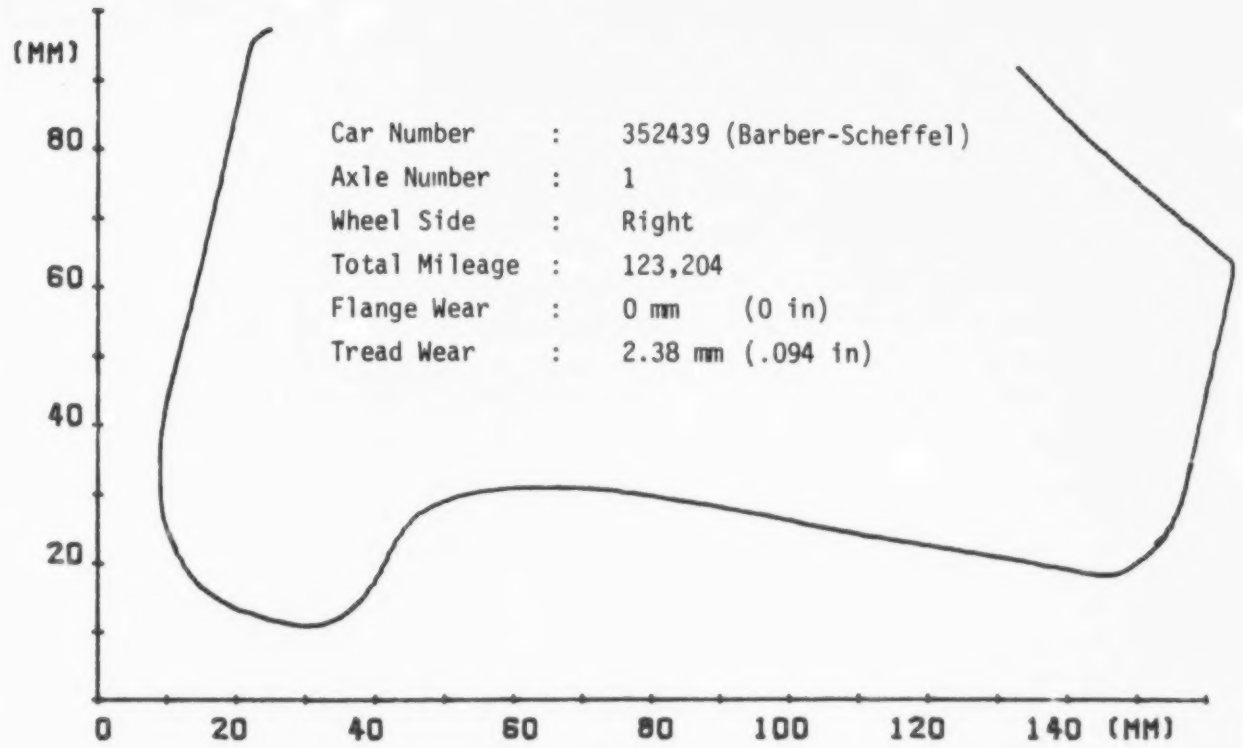
FILE: W10.05.8 ID: 228410



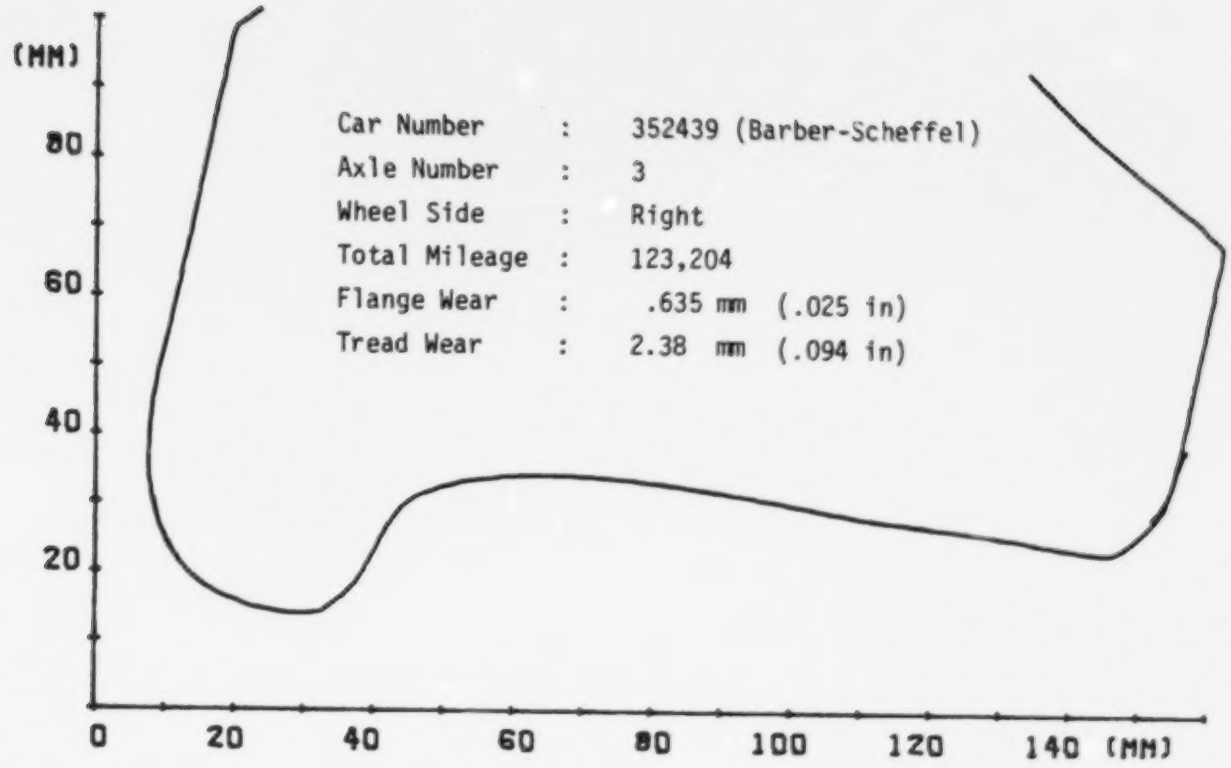
Car Number	:	351728 (Reference)
Axle Number	:	4
Wheel Side	:	Left
Total Mileage	:	130,666
Flange Wear	:	3.175 mm (.125 in)
Tread Wear	:	1.9 mm (.075 in)



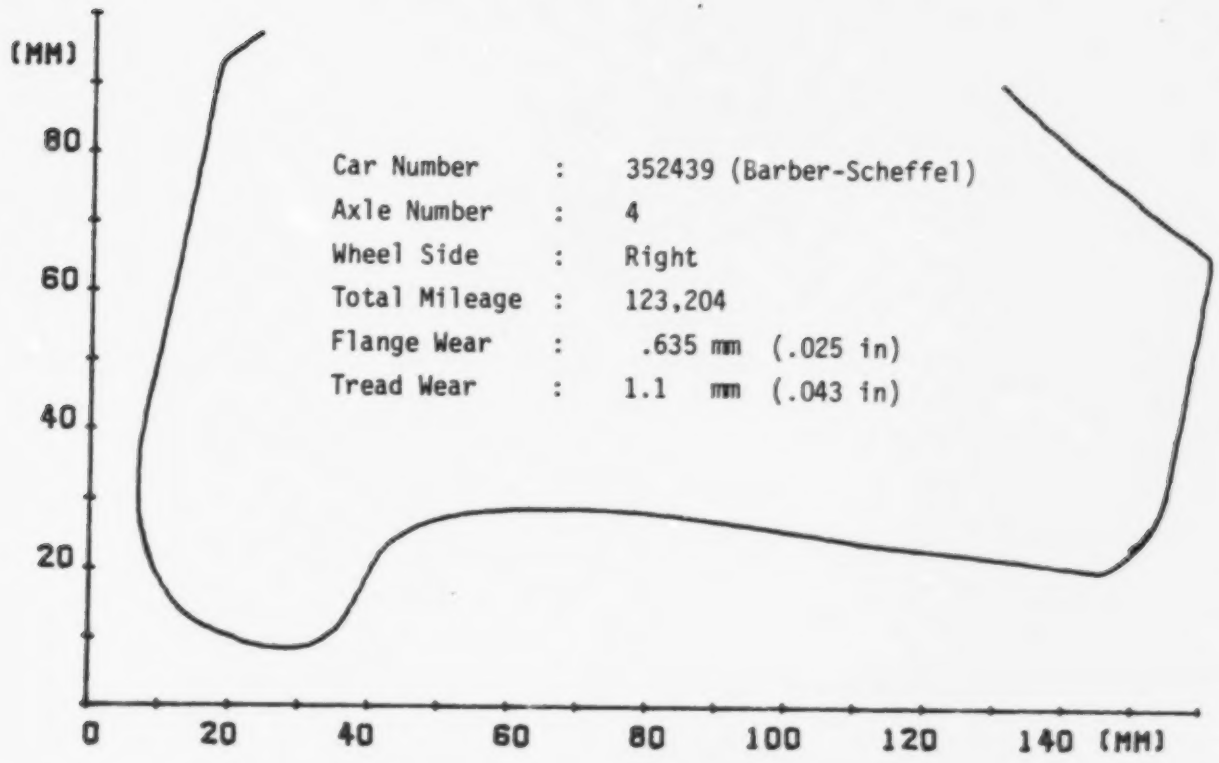
FILE: W10.05.8 ID: 239100



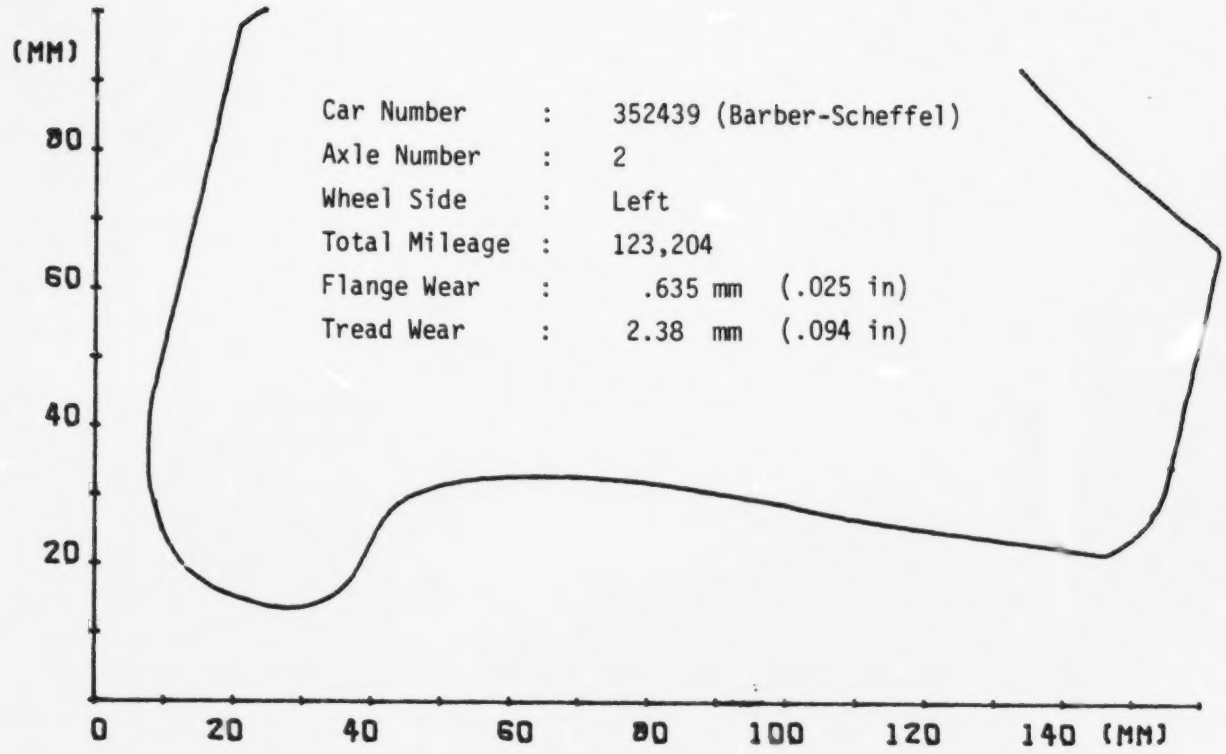
FILE: W10.05.8 ID: 239300



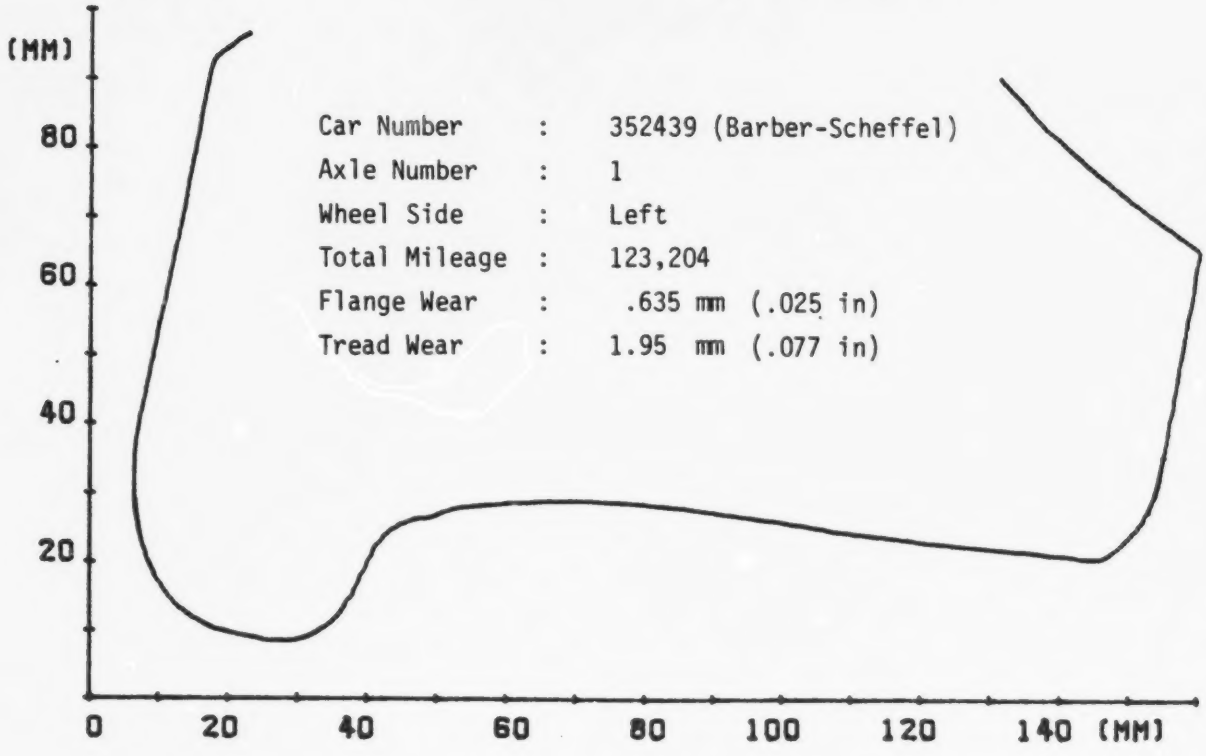
FILE: W10.05.8 ID: 239400



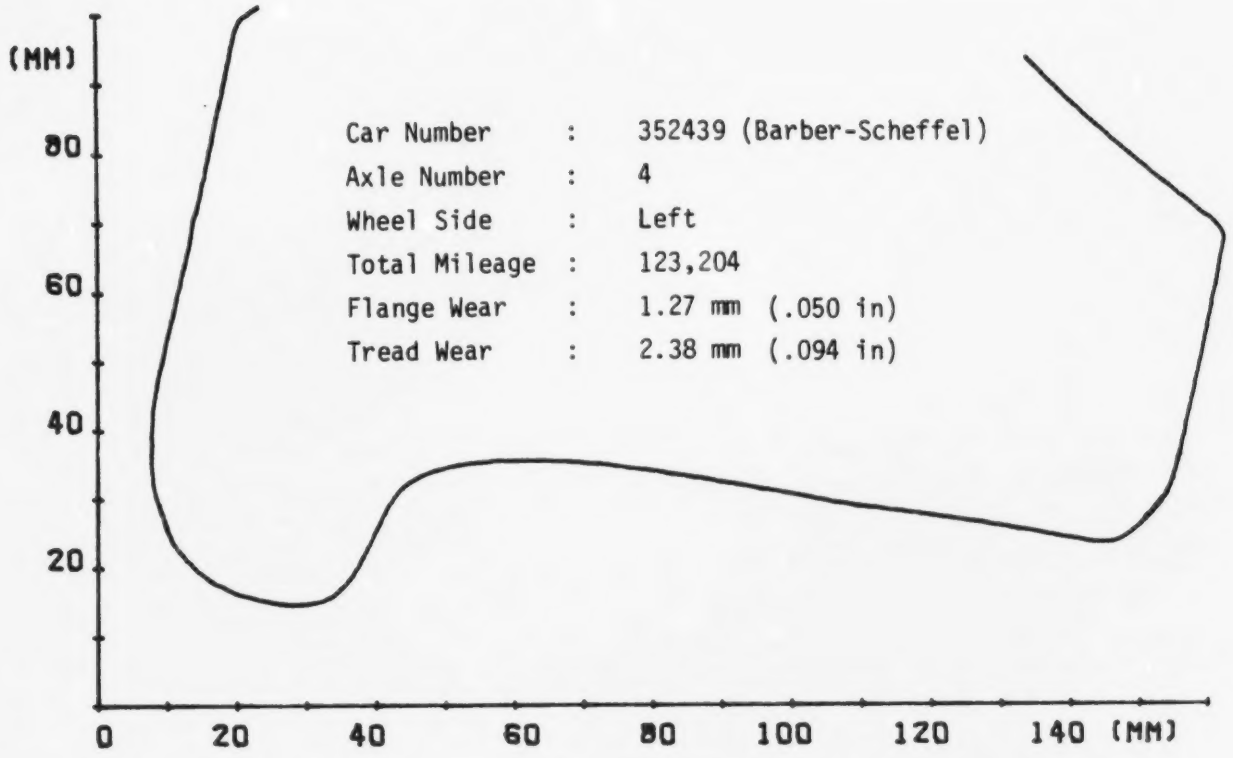
FILE: W10.05.8 ID: 239210



FILE: W10.05.8 ID: 239110

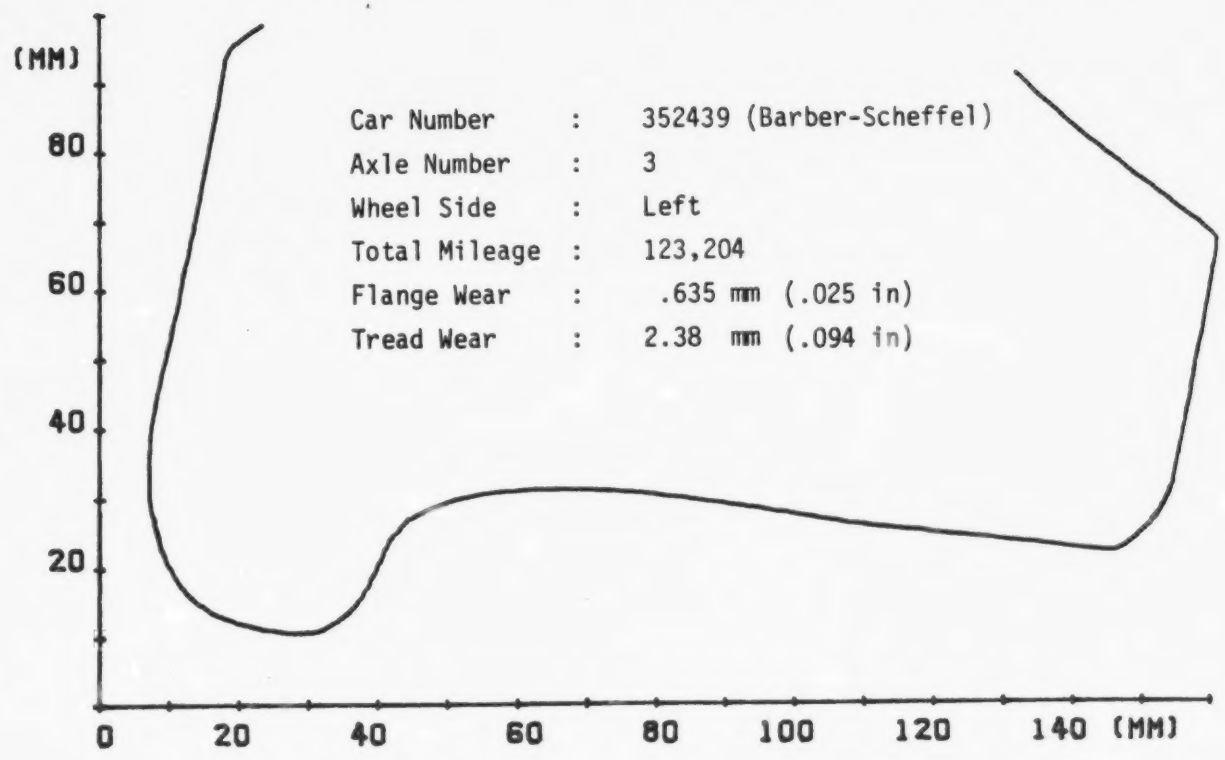


FILE: W10.05.8 ID: 239410



Car Number	:	352439 (Barber-Scheffel)
Axle Number	:	4
Wheel Side	:	Left
Total Mileage	:	123,204
Flange Wear	:	1.27 mm (.050 in)
Tread Wear	:	2.38 mm (.094 in)

FILE: W10.05.8 ID: 239310



Car Number	:	352439 (Barber-Scheffel)
Axle Number	:	3
Wheel Side	:	Left
Total Mileage	:	123,204
Flange Wear	:	.635 mm (.025 in)
Tread Wear	:	2.38 mm (.094 in)

APPENDIX II

SELF-STEERING TRUCK EVALUATION
PROGRESS REPORTS

PROGRESS REPORT NO. 1

December 1981-January 1982

SELF-STEERING TRUCK ACQUISITION AND EVALUATION IN UNIT COAL TRAIN OPERATION

Contract
Serial No. 09SD.T8200-0-0532

PROGRESS REPORT TO TRANSPORTATION RESEARCH AND DEVELOPMENT CENTRE

BARBER-SCHEFFEL SELF-STEERING TRUCKS

In December 1981, five carsets of Barber-Scheffel trucks were assembled and installed on five 100-ton bathtub coal cars at CP Rail's Ogden Shops in Calgary. Another three bathtub coal cars were equipped with conventional trucks for baseline comparison. The five test cars and three base cars were all equipped with CP standard Heumann profile wheels. Test car numbers are as follows:

Cars equipped with Barber-Scheffel trucks	Cars equipped with Conventional trucks
CP 352439	CP 351530
352440	351581
532441	531728
532442	
532443	

Wheel measurements were initially made at Ogden Shops on all test cars prior to releasing them into revenue service on the Pacific Region.

On arrival of bathtub coal cars equipped with Barber-Scheffel trucks to Robert's Bank; after their first loaded trip; an inspection was performed on trucks. The diagonal cross arms on five trucks of 3 cars were found to be severely bent due to interference with centre pin at time of assembly. Cars CP 352439, 352441 and 352443 were bad ordered after unloading coal and sent to Coquitlam for replacement of cross arms.

All eight test cars are presently operating in revenue service on the Pacific Region. The test cars are coupled together and continue to operate as a unit. Measurements of wheel wear will be made on the test cars when they accumulate approximately 60,000 miles. In addition to wheel wear measurements to be made with a calibrated AAR finger gauge, wheel profiles on some of the test cars will be measured by a wheel profilometer.

PROGRESS REPORT NO. 2

February - March 1982

SELF-STEERING TRUCK APPRAISAL PROGRAM

Contract
Serial No. 09SD.T8200-0-0532

BARBER-SCHEFFEL SELF-STEERING TRUCKS

The five test cars and the three reference cars were coupled to form a special test consist and placed in unit coal train revenue service operation on the Pacific Region. The test cars have been operating since January 1, 1982 and have accumulated approximately 21,000 miles of service to the end of March, 1982.

Measurements of wheel wear will be made on the test cars in July, 1982. Wheel wear measurements will be made with a calibrated AAR finger gauge. In addition, wheel profiles on some of the test cars will be measured by a new wheel profilometer presently being fabricated at CP Angus Shops.

DR-2 SELF-STEERING TRUCKS

In May 1982, five carsets of DR-2 trucks will be assembled and installed on five 100-ton bathtub coal cars presently under construction at National Steel Car in Hamilton. The five test cars will be equipped with CP Standard Heumann profile wheels.

Wheel measurements will be made at National Steel Car on all test cars prior to release into revenue service on the Pacific Region.

The five test cars equipped with DR-2 self-steering trucks will be coupled to the eight test cars thus increasing the number of cars of the special Radial truck test consist to thirteen. There will be no need to add other base cars to this special test consist, as the three bathtub coal cars equipped with conventional Barber S-2 trucks will also serve as base cars for evaluating DR-2 truck performance.

PROGRESS REPORT NO. 3

April-May 1982

CANADIAN PACIFIC LIMITED

SELF-STEERING TRUCK APPRAISAL PROGRAM

Contract
Serial No. 09SD.T8200-0-0532

BARBER-SCHEFFEL SELF-STEERING TRUCKS

The five test bathtub coal cars equipped with Barber-Scheffel trucks and the three reference bathtub coal cars equipped with Barber S-2 trucks continue to operate as a special test consist in unit coal train revenue service on the Pacific Region. This special Radial Truck test consist has been operating since January 1, 1982 and the cars have accumulated approximately 35,000 miles of service to the end of May, 1982.

It is anticipated that these cars will accumulate 60,000 miles by mid-August, therefore, arrangements will be made to carry out the first set of wheel wear measurements at that time. Wheel wear measurements will be made with a calibrated AAR finger gauge. In addition, wheel profiles on a number of preselected wheels of the test cars will be measured by the new wheel profilometer presently in its final stage of fabrication at CP Angus Shops.

DR-2 SELF-STEERING RETROFIT TRUCKS

In the latter part of May and first week in June, five carsets of DR-2 steerable axle trucks were assembled at National Steel Car in Hamilton. These trucks were applied on the last five carsets of CP Rail's order of 410 bathtub coal cars with National Steel Car.

Wheel measurements and other pertinent truck dimensions were taken at National Steel Car on all test trucks to be used for our Radial Truck Test program prior to assembly of the last five bathtub coal cars.

The car numbers of bathtub coal cars equipped with DR-2 steerable axle trucks are as follows:

CP 352849
CP 352850
CP 352851
CP 352852
CP 352853

One steering arm and corresponding interconnecting links on CP 352853 were strain gauged by Dofasco's Research Department to measure the magnitude of forces developed in the steering arm and the lateral load experienced between two connected steering arms. To record these data, an instrument box was mounted at the 'A' end of coal car CP 352853.

The five test cars equipped with the DR-2 steering trucks will be forwarded to the Pacific Region to be placed with our Radial Truck Test consist thus increasing the number of test cars to thirteen.

CANADIAN PACIFIC LIMITED

SELF-STEERING TRUCK APPRAISAL PROGRAM

PROGRESS REPORT NO. 4

June-July 1982

Contract
Serial No. 09SD. T8200-0-0532

BARBER-SCHEFFEL SELF-STEERING TRUCKS

Five test bathtub coal cars equipped with Barber-Scheffel trucks and three reference bathtub coal cars equipped with conventional Barber S-2 trucks have been introduced, as a special test consist, in unit coal train revenue service. These cars have been operating on the Pacific Region since January 1, 1982. The special radial truck test consist has accumulated approximately 53,000 miles of service to the end of July, 1982.

As these cars will have accumulated approximately 60,000 miles by the end of August, 1982 arrangements will be made to carry out the first set of wheel wear measurements at that time or at the latest in the early part of September, 1982. Wheel flange and tread wear will be assessed by the use of a readily available calibrated AAR finger gauge. Our new wheel profilometer will be available for measurement of radial truck wheel profiles, after it has undergone calibration. It is expected to have the calibrated wheel profilometer ready for use in the early part of September, 1982.

DR-2 SELF-STEERING RETROFIT TRUCKS

Five carsets of bathtub coal cars equipped with DR-2 steerable axle trucks were placed in revenue service operation in June, 1982. These cars were placed with the Barber-Scheffel test consist thus increasing the number of test cars in the radial truck test consist to thirteen.

As reported previously, one steering arm and the corresponding interconnecting links on coal car CP 352853 were strain gauged by Dofasco's Research Department to measure the magnitude of forces developed in the steering arms. An instrument box mounted at the 'A' end of coal car CP 352853 was used to store the data. These data have now been collected by Dofasco Research personnel and are being analyzed. The results of this test will be reported in our next progress report.

It is anticipated that the cars equipped with DR-2 steerable axle trucks will accumulate 60,000 miles by the latter part of the winter.

CANADIAN PACIFIC LIMITED

SELF-STEERING TRUCK APPRAISAL PROGRAM

PROGRESS REPORT NO. 5

AUGUST-SEPTEMBER 1982

Contract
Serial No. 095D. T8200-0-0532

BARBER-SCHEFFEL SELF-STEERING TRUCKS

The special test consist of bathtub coal cars equipped with Barber-Scheffel radial trucks and conventional Barber S2 trucks was pulled out of revenue service on September 28, 1982, for truck inspection and wheel profile measurements to be carried out.

Wheel profile measurements were carried out on September 30, 1982 at CP Rail's Revelstoke yard. At the time of inspection, these cars had accumulated approximately 70,000 miles since their introduction into revenue service in January of this year.

It was the first field trial test for the new wheel profilometer which proved to perform efficiently and reliably. Wheel profiles of all eight test cars were collected. Furthermore, wheel flange and tread wear were assessed by the use of a calibrated finger gauge.

On inspection of the Barber-Scheffel truck components no major exceptions were noted. The cross diagonal arms were closely inspected and found to be in good working condition. On car CP 352441 it was noted that its side frame pedestal liners were showing a slight wear condition. The results of wheel wear measurements will be reported in our next progress report.

DR-2 SELF-STEERING RETROFIT TRUCKS

The five carsets of bathtub coal cars equipped with DR-2 steerable axle trucks continue to operate in revenue service. These cars were placed in revenue service operation in June, 1982 and therefore have not yet reached their 60,000 mile inspection point.

The data from the strain gauges located on one of the steering arms and the corresponding interconnecting links on coal car CP 352853 was collected by Dofasco's Research personnel but the results of the analysis is not yet available from Dofasco.

CANADIAN PACIFIC LIMITED

RADIAL AXLE TRUCK APPRAISAL PROGRAM

PROGRESS REPORT NO. 6

Period: October - November 1982

Contract
Serial No. 095D.T8200-0-0532

BARBER-SCHEFFEL SELF-STEERING TRUCKS

The results of wheel wear measurements carried out with the use of a calibrated AAR finger gauge indicate that the average flange wear experienced by Barber-Scheffel truck wheels is about 1/3 that of conventional Barber S2 truck wheels. Measurements of tread wear (flange height), on the other hand, showed no appreciable difference.

Wheel profile digital data collected by the use of the new wheel profilometer was processed and wheel tread and flange profiles were plotted. The amount of metal removed due to wear will be determined once the software package for matching wheel profiles is implemented.

DR-2 SELF-STEERING RETROFIT TRUCKS

The five carsets of bathtub coal cars equipped with DR-2 steerable axle trucks are operating satisfactorily in revenue service.

It is envisaged to carry out the first set of wheel wear measurements in the latter part of January or early February 1983. These cars will then have accumulated between 60,000 and 70,000 miles.

Wheel wear measurements will be made with a calibrated AAR finger gauge. In addition, wheel profiles on a number of preselected wheels of the test cars will be measured by the new wheel profilometer.

CANADIAN PACIFIC LIMITED

RADIAL AXLE TRUCK APPRAISAL PROGRAM

PROGRESS REPORT NO. 7

Period: December 1982 - February 1983

Contract
Serial No. 09SD.T8200-0-0526

BARBER-SCHEFFEL SELF-STEERING TRUCKS

The special radial truck test consist consisting of five bathtub coal cars equipped with the Barber-Scheffel trucks continued to operate satisfactorily in unit coal train service. These cars have accumulated approximately 116,000 miles since their introduction into revenue service operation in January 1, 1982. It is envisaged to carry out the second set of wheel profile measurements in the latter part of April or early May. These cars will have accumulated approximately 140,000 miles of service by then.

The result of the first set of wheel profile measurements carried out after approximately 73,000 miles of revenue service was reported in our previous progress report. The amount of wheel flange and tread cross-sectional area loss will be established once the software package for matching wheel profiles is implemented.

To date there has been no reports of wheelset changeouts on any of the five carsets of bathtub coal cars equipped with the Barber-Scheffel trucks. One of the wheelsets of the reference bathtub coal car CP 351728 equipped with the conventional Barber S2 trucks, however, was changed out on February 23, 1983 after approximately 110,000 miles of service.

DR-2 SELF-STEERING RETROFIT TRUCKS

The five carsets of bathtub coal cars equipped with DR-2 steerable axle trucks are operating satisfactorily in revenue service.

These cars were introduced into revenue service operation in June 1982 and have accumulated approximately 70,000 miles of service (February 1983). The first set of truck inspection and wheel profile measurements will be carried out on March 9, 1983 at Revelstoke.

Wheel wear measurements will be made with a calibrated AAR finger gauge. In addition, wheel profiles will be measured by the use of the new wheel profilometer.

CANADIAN PACIFIC LIMITED

RADIAL AXLE TRUCK APPRAISAL PROGRAM

PROGRESS REPORT NO. 8

Period: March-April, 1983

Contract
Serial No. 09SD.T8200-0-0526

BARBER-SCHEFFEL SELF-STEERING TRUCKS

Bathtub coal cars CP 352439 to CP 352443 equipped with Barber-Scheffel trucks continued to operate satisfactorily, in unit coal train service, in the Pacific Region.

Inspection of wheel profiles and truck steering components is scheduled to be carried out on May 10 and 11, 1983 at Revelstoke. Reference bathtub coal cars CP 351530, CP 351581 and CP 351728 will also be called into CP Rail's Revelstoke shop for inspection.

These test cars will have accumulated approximately 130,000 miles of service by then. They were last inspected in September 30, 1982 at Revelstoke.

DR-2 SELF-STEERING RETROFIT TRUCKS

The five bathtub coal cars equipped with trucks retrofitted with over-the-bolster steering arms were called into CP Rail's shop at Revelstoke for inspection of wheel profiles and truck steering components.

On March 9 and 10, 1983 wheel profiles were collected by CP Research personnel using the new wheel profilometer. Truck steering components were jointly inspected by a representative from Dofasco Inc. and CP Research.

On inspection of wheel tread and flange surfaces no defects were found. Steering arm interconnecting linkages were found to be in good operating condition with the exception of two links, located at the 'B' end truck of car CP 352849. They appeared to have damaged spherical bearings.

Test car CP 352849 was held at Revelstoke until such time that new replacement links were received from Dofasco. The new bearings are not identical to the ones presently installed on test cars. Dofasco has recommended the use of a "Torrington" bearing which comes complete with seals as an integral part of the bearing assembly. This type of seal has been tried on other applications with good results.

It may be necessary to changeout all links on all five test cars, as during inspection, it was not possible to see all areas of the trucks clearly and therefore, it is probable that some of the other links had also become defective. During inspection of those links, some were felt to be experiencing excessive lateral play. This may be an indication of weakness of this truck steering component on all test cars.

Wheel flange and tread wear data collected by the use of a calibrated AAR finger gauge indicate that the average flange wear experienced by the DR-2 truck wheels is relatively lower compared to wheels of the Barber S-2 trucks. There was no appreciable difference between the tread wear on wheels of both types of trucks.

CANADIAN PACIFIC LIMITED

RADIAL AXLE TRUCK APPRAISAL PROGRAM

PROGRESS REPORT NO. 9

PERIOD: MAY-JUNE, 1983

Contract
Serial No. 09SD.T8200-0-0526

Barber-Scheffel Self-Steering Trucks

On May 10, 1983 truck inspection and wheel profile measurements were carried out on the five bathtub coal cars equipped with Barber-Scheffel trucks and the three reference coal cars equipped with the conventional Barber S2-C trucks.

At the time of inspection this special radial truck test consist had accumulated an average of 130,000 miles of revenue service. It was introduced into revenue service operation, in the Pacific Region, in January 1982 and was last inspected on September 30, 1982 at Revelstoke.

Wheel profile measurements and truck inspection were carried out at CP Rail's Revelstoke yard. On inspection of the Barber-Scheffel truck components no defects were found. All main truck components such as side frame housing which support shear pads and engage bearing adaptors, and diagonal bar connectors, were found to be in good operating condition.

Wheel profile measurements were carried out by the use of CP wheel profilometer. Although wheel flange and tread wear will be assessed from wheel profiles obtained after processing of data, it was evident from wheel flange thickness measurements carried out by a calibrated AAR finger gauge that these wheels exhibited much less flange wear compared to wear experienced by wheelsets on the reference cars equipped with conventional Barber S2-C trucks. In fact, at 130,000 miles, the loss in wheelset flange thickness on the Barber-Scheffel cars is approximately 1/4 that of the control cars equipped with Barber S2-C trucks. Tread wear of the Barber-Scheffel truck wheels, on the other hand, was comparable to values measured on wheels of reference cars.

On inspection of wheels of reference cars equipped with conventional Barber S2-C trucks, it was observed that flange wear of those wheels was noticeably more than wheels of the Barber-Scheffel trucks. No defects were observed on the tread surface of these wheels. A number of wheels,

however, experienced metal build up on the flange, one of these measured up to 1/8" all around the wheel flange circumference.

DR-2 Self-Steering Retrofit Trucks

On May 10, 1983 the five bathtub coal cars equipped with DR-2 over-the-bolster steering arms were removed from revenue service for replacement of steering arm linkages.

On inspection of the links which were replaced, it was observed that a good number were deformed, and one in fact had a spherical bearing that had come loose. Furthermore, during defective link changeout it was observed that one of the steering arms was slightly gouged at the clevis where it joins the steering arm link. The defective links were sent back to Dofasco for further examination and testing.

All five bathtub coal cars with new steering arm links were placed back into revenue service operation. It is envisaged to carry out the next set of inspection and wheel profile measurements in September 1983.

Modified Elasto-Cushion Truck Tests

High speed stability and curving performance tests will be carried out on Elasto-Cushion trucks modified with the incorporation of a truck stiffening member. These tests were initially scheduled for July 1983, but had to be postponed because of involvement of Research personnel in other priority research activities. The tests are now re-scheduled to commence in the month of September 1983.

CANADIAN PACIFIC LIMITED

RADIAL AXLE TRUCK APPRAISAL PROGRAM

PROGRESS REPORT NO. 10

Period: July-August, 1983

Contract
Serial No. 09SD.T8200-0-0526

BARBER-SCHEFFEL SELF-STEERING TRUCKS

Bathtub coal cars CP 352439 to CP 352443, equipped with Barber-Scheffel trucks, continued to operate in unit coal train service in the Pacific Region. They were last inspected on May 10, 1983 at Revelstoke at the completion of 130,000 miles of service operation and have now accumulated an average of 154,000 miles at the end of August, 1983.

The results of wheel measurements at 130,000 miles indicate that the loss in wheelset flange thickness on the Barber-Schefel trucks is reduced to approximately 1/4 that of the control cars equipped with Barber S-2 trucks. The tread wear on wheels of the Barber-Scheffel trucks was also lower compared to wear experienced by the control cars. The average tread wear was found to be reduced by as much as 22%.

The amount of wheel flange and tread cross-sectional area losses were also established by the use of the wheel profilometer device. These values were derived through automatic matching of measured wheel profiles. The results indicate that the flange cross-sectional area loss for the Barber-Scheffel cars is reduced to approximately 22% of that developed on the control cars. The average tread area wear on wheels of the Barber-Scheffel trucks was found to be reduced by as much as 35% compared to wear experienced by the control cars.

Bathtub coal car CP 352442 experienced failure of one lateral strut; which runs parallel to the truck bolster; at the R1 and L1 location. The strut broke off at the R1 location after approximately 150,000 miles of revenue service operation. A replacement strut was provided by Standard Car Truck Company and car CP 352442 was fitted with new strut and placed back into revenue service operation.

Laboratory tests carried out by Standard Car Truck Company on this truck component revealed that the failure was caused by reversed bending moments to which the Barber-Scheffel truck lateral strut is subjected during service operation. This cyclical bending movement is causing fatigue failure at the end corner of the member where a stud is welded to the rod. A new design incorporating a resilient bushing at the failed location of the rod has been completed and new components are being fabricated. In the near future all existing lateral struts will be replaced by new ones with rubber bushings.

DR-2 SELF-STEERING RETROFIT TRUCKS

All five bathtub coal cars equipped with the DR-2 over-the-bolster steering arms were fitted with new steering arm links with "Torrington" type spherical bearings and returned to revenue service operation. Changeout of links took place in May, 1983 and it is envisaged to carry out the next set of truck inspection and wheel profile measurements in September 1983. These cars will have accumulated an additional 50,000 miles of revenue service by then, thus bringing total average service mileage accumulated to 123,000 miles by the end of September 1983.

MODIFIED ELASTO-CUSHION TRUCK TESTS

Tests were conducted to determine the stability and curving performance of conventional three-piece 100-ton trucks rigidized by means of a stiffening linkage and equipped with elastomeric shear pads.

The curving tests were carried out on a 5° curve with fully laden 100-ton bathtub coal cars with new Heumann wheels.

The hunting tests were carried out on light 100-ton bathtub coal cars with service worn wheels to a maximum speed of 65 mph.

The data from the tests conducted in September are currently being analyzed and a report on the findings will be issued when the analyses are completed.

CANADIAN PACIFIC LIMITED

RADIAL AXLE TRUCK APPRAISAL PROGRAM

PROGRESS REPORT NO. 11

Period: September-November 1983

Contract
Serial No. 09SD.T8200-0-0526

BARBER SCHEFFEL SELF-STEERING TRUCKS

Barber Scheffel trucks accumulated an additional 50,000 miles since they were last inspected in May, 1983 at Revelstoke (after 130,000 miles of revenue service operation). During this period the five bathtub coal cars, CP 352439 to CP 352443, equipped with these radial trucks continued to operate satisfactorily in unit coal train service in the Pacific Region.

The results of wheel profile measurements of the Barber-Scheffel and reference Barber S2-C wheels at 130,000 miles indicated that the flange cross-sectional area loss of the Barber-Scheffel truck wheels is approximately 22% of that developed on wheels of the control cars. The tread cross-sectional area loss of wheels of the Barber-Scheffel trucks was found to be approximately 65% that developed on the wheels of the control cars.

A paper entitled "Comparative Performance of New Generation Freight Car Trucks" was presented at the Freight Car Truck Performance Conference which included wheel flange and tread cross-sectional area losses, computed from wheel profile measurements, for the self-steering Barber-Scheffel and the DR-2 trucks as well as the reference Barber S2-C trucks. Finger gauge measurements obtained by the use of a calibrated AAR finger gauge were also included in the paper.

Modified lateral struts incorporating resilient bushings at the end stud connections have been produced by Standard Car Truck Company. They will be forwarded to Revelstoke, B.C. for changeout of all Barber-Scheffel truck lateral struts. It is envisaged to carry out this changeout program in December, 1984.

It is our intention to continue to monitor wheel wear on the five bathtub coal cars equipped with Barber-Scheffel trucks until such time as they accumulate 250,000 miles of revenue service operation. This test program

will be part of our radial axle truck test program in 1984 where in addition to the Barber-Scheffel and the DR-2 self-steering trucks, other types of 100-ton radial trucks will be tested to assess their effectiveness for retrofit on conventional 100-ton bathtub coal car trucks.

DR-2 SELF-STEERING RETROFIT TRUCKS

On September 28 and 29, 1983 DR-2 truck inspection and wheel profile measurements were carried out at Revelstoke on the five bathtub coal cars equipped with these trucks. The cars were introduced to revenue for testing in June 1982 and were last inspected at Revelstoke on March 9, 1983 after having accumulated an average of 70,000 miles of service. At the time of the second inspection these cars had accumulated an average of 130,000 miles of revenue service.

Inspection of the steering arm links on cars CP 352849 to CP 352853 revealed that the "Torrington" spherical bearings had failed to the extent that they were all missing with the exception of links on car CP 352853 which exhibited damaged bearings at the 'A' end truck and intact (good) bearings at the 'B' end truck. During a closer look at the links at the 'B' end of car CP 352853, it was noticed that the outer races of the spherical bearings had shifted slightly downward as a result of being subjected to vertical downward forces higher than the friction force which holds the bearing inside the link.

Even though problems were experienced with the steering links of the DR-2 trucks, the average flange wear of wheels of the DR-2 trucks was approximately 1/4 that of the control cars after 130,000 miles of revenue service operation. The tread wear obtained from the finger gauge measurements showed that, similar to the Barber-Scheffel truck wheels, the DR-2 truck wheels exhibited less tread wear as compared to the reference Barber S2-C truck wheels.

It was established that the steering arm interconnecting bearing linkages are not adequate to withstand forces developed at the steering arm connections. Testing of the DR-2 trucks was suspended and the DR-2 over-the-bolster steering arms were removed from the test cars and the cars were returned to revenue service operation.

A new link connection design will be provided by Dofasco after which extensive laboratory testing will be carried out on the steering arms before they are re-introduced to revenue service testing. This work will form part of our continued radial axle truck test program in 1984.

MODIFIED ELASTO-CUSHION TRUCK TESTS

A series of curving performance and high speed stability tests was conducted on two 100-ton bathtub coal cars, equipped with elasto-cushion trucks rigidized by means of insertion of a rigid member between the truck sideframes, and a reference car with conventional trucks.

The hunting tests were carried out, with service worn wheels on the test cars, in speed increments of 5 mph from 30 mph to 65 mph on a two mile section of track with continuous welded rail.

A series of curving tests was conducted on a 5° curve at the balance speed, and above and below the balance speed for the curve with the two test cars and a reference conventional car equipped with Barber S2-C trucks. All test cars were equipped with new Heumann profile wheels.

Data from the study on the rigidized truck tests is currently being analyzed and a report on the findings will be issued on completion of the analysis.

APPENDIX III

RIGIDIZED TRUCK TEST PROGRESS REPORT

RIGIDIZED TRUCK TESTS

A series of curving performance and high speed stability tests was conducted on two 100-ton bathtub coal cars, equipped with elasto-cushion trucks rigidized by means of insertion of a rigid member between the truck sideframes, and a reference car with conventional trucks. These tests were undertaken to further investigate the performance of modified 3-piece trucks as results of earlier test work carried out showed that improved curving performance could be obtained with the elastomeric shear pads installed between the bearing adaptor and the sideframe pedestal roof, provided the truck did not parallelogram.

The hunting tests were carried out, with service worn wheels on the test cars, in speed increments of 5 mph from 30 mph to 65 mph on a two mile section of track with continuous welded rail.

A series of curving tests was conducted on a 5° curve at the balance speed, and above and below the balance speed for the curve with the two test cars and a reference conventional car equipped with Barber S2-C trucks. For the curving tests the three test cars were equipped with new Heumann profile wheels.

Data from the study on the rigidized truck tests is currently being analyzed and a report on the findings will be issued on completion of the analysis.